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ABSTRACT

The major environmental problem of acid precipition is addressed through a series of activities contained in this guide for teachers of grades 6 through 12. Exercises are provided to help students learn science inquiry skills, facts, and concepts while focusing on the acid rain situation. Activities are organized by content areas. These include: (1) biological sciences (investigating the effects of acid rain on beans, seedlings, radishes, amphipods, earthworms, and hay infusions); (2) earth science (working with rocks, soil and weather conditions); (3) physical sciences (dealing with logarithms to express the pH scale, carrying out monitoring projects on anthrogenic emissions); and (4) social sciences (focusing on analysis of cartoons on acid rain and survey sampling). Each activity contains background information, objectives, needed materials, and guidelines for the teachers as well as student instruction and/or data sheets, and tests on each activity. (ML)

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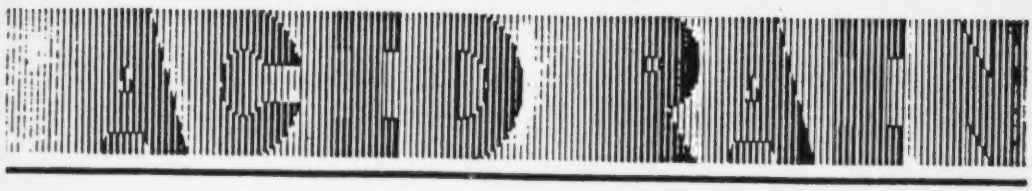

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ACID PRECIPITATION AWARENESS, Title IV-C, ESEA and THE ACID RAIN FOUNDATION, INC.

ACID PRECIPITATION LEARNING MATERIALS
Science, Environmental and Social Studies, Grades 6-12

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THE ACTIVITIES

These activities do not in any way constitute a course. These activities suggest some ways in which teachers can help students learn science while also learning about a major environmental problem: acid precipitation.

It is our hope that the activities can be used flexibly. One of the problems in writing learning materials is achieving the proper balance between specificity -- careful sequencing of ideas, pre-specified teacher actions, appropriate student responses, all of the curricular content material needed -- and sketchiness -- trial-and-error procedures, lack of guidance, and unclear directions.

We think the activities provide provocative suggestions and promote the process of science education as continuous inquiry while also emphasizing the importance of facts and content.

QUESTIONS

The 1979 Annual Report of the Council on Environmental Quality identified acid rain as one of the two most serious global environmental problems associated with the combustion of fossil fuels (carbon dioxide buildup is the other).

Many of these activities assume a general background in and familiarity with acid precipitation. Many films, slidesets, tapes and transparencies are available.

After students have reviewed any of these materials, some discussion questions you might consider include:

- What is the main concern about acid precipitation at this time?
- What are the major causes of acid precipitation?
- What evidence is presented that convinces you that rain has become increasingly acidified in the past few years? What evidence is presented that the problem is becoming geographically widespread? Do you think the evidence is authentic? Why?
- What is known about acid precipitation? Unknown?
- If the hypothesis that acid precipitation is causing damage to natural ecosystems/lakes/statuary/agricultural systems (choose one or use all of them individually) is true, then what kinds of evidence were presented to support the hypothesis?
- Is any evidence presented that acid rain is good for you or planet Earth? How good? If we eliminated or greatly reduced acid rain, what damage would occur?
- What are some of the costs of acid rain? Which ones should concern us most?
- What are some of the unanswered questions about acid rain?
- What options for reducing SO_x (Sulfur oxides) and NO_x (Nitrogen oxides) emissions are available to us? Rank order them in terms of: (a) economic cost, (b) political costs, and (c) benefits to earth's natural and agricultural ecosystems. Which one is the easiest to make happen?
- Is there a link between acid precipitation and energy conservation? What is it?
- Is the occurrence of acid precipitation another reason for encouraging energy conservation?
- What would you say to someone who said acid precipitation: (1) "is just another government trick" or (2) "is just another unproved claim of those environmentalists" or (3) "will be solved by technology"?
- From your point-of-view, is this presentation balanced? What convinces you? How could you find out?
- What are some of the possible effects on humans? Are these effects more serious, less serious or about the same as the real and potential effects on plants and animals?
- Based on what we know about acid precipitation, what should we do about it?

LABORATORY SAFETY

Students in science laboratories are always exposed to some degree of risk. The principal hazards vary from discipline to discipline but dangers can be minimized if some simple techniques of laboratory safety are followed. Teachers are responsible for the safety of their students and reasonable and prudent safety measures.

These activities assume that teachers: (1) know the potential hazards; (2) are responsible for the safety of their students; (3) are responsible for reasonable and prudent safety measures and that the rules are enforced; NO EXCEPTIONS; (4) have instructed students on proper laboratory and laboratory safety procedures; and (5) are models of appropriate laboratory safety consciousness.

It is recommended that:

* potential hazards are identified before the lab, e.g., liquids should not be poured above eye level.
* students are instructed on the appropriate use of safety equipment.

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* good housekeeping practices are developed and routinely enforced.

* safety posters are displayed in the lab.

* students are prohibited from eating (includes beverages) in the lab.

* bottles of acid stock solutions should not clutter working surfaces or be stored where they can be bumped into or knocked off shelves.

* safety goggles be worn when acid solutions are being used. They should be "industrial quality eye protection devices" which meet the standards of the American National Standard Institute.

* you write safety instructions for students and develop a letter to parents/guardians informing them of your laboratory safety instructions.

A valuable laboratory safety publication from the Minnesota Department of Education, "Safety Guidelines for High School Chemistry" is available by writing: Science Curriculum Specialist, Minnesota Department of Education, 550 Cedar Street, St. Paul, MN 55101.

Additional information related to the topic of safety in the science classroom is available from:

ERIC Information Bulletin No. 3. 1980. "Safety in the Science Classroom" (ERIC Clearinghouse for Science, Mathematics and Environmental Education, The Ohio State University, 1200 Chambers Road, 3rd Floor, Columbus, OH 43212. Free).

National Science Teachers Association. "Safety in the Elementary Science Classroom" and "Safety in the Secondary Science Classroom" (NSTA Publications, 1742 Connecticut Avenue NW, Washington, DC 20009. The elementary flip chart and secondary manual are available for: $5.00 plus $1.00 handling).

ANIMAL WELFARE: AN EMERGING CLASSROOM ISSUE

Some of the activities involve the use of invertebrate animals. Some of the organisms will die as a result of the procedures. They will not die from mishandling or from lack of proper care. Some states -- Missouri and New York -- have proposed legislation that would restrict or prohibit experiments on animals.

Two national science teachers associations have adopted guidelines that ban classroom experiments harming animals. The National Association of Biology Teachers (NABT) and the National Science Teachers Association (NSTA) hope to end animal abuse in elementary and secondary schools. The code of practice recommended by the National Science Teachers Association can be found in The Science Teacher (September 1980, pp 57-58).

The issue of animal use in experiments is not an easy one. You will have to answer and address it in your classroom. In general, most of us are more concerned about vertebrates than invertebrates, at least in the lab. Vertebrates and invertebrates can die in aquatic ecosystems from the effects of acid rain and the level of concern appears to change from one of animal welfare to the loss, say, of a sport or recreational fishery such as the loss of trout in Adirondack lakes.

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Life Sciences

Some biological consequences of acidification on amphipods (Gammarus)

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Overview

The responses of Gammarus, a small crustacean that is easily observed with the naked eye, to varying levels of pH is investigated. Gammarus select the optimum pH.

Objectives

After this activity students should be able to:

- identify the essential steps in approaching a problem scientifically.
- investigate variables and to discover effective ones.
- appreciate the need to control variables and use controls in investigations.
- describe conditions which promote changes in living things.
- describe observable effects of acid rain on organisms.
- know some ways to investigate and measure properties of living things.
- consider the role of science in everyday life.

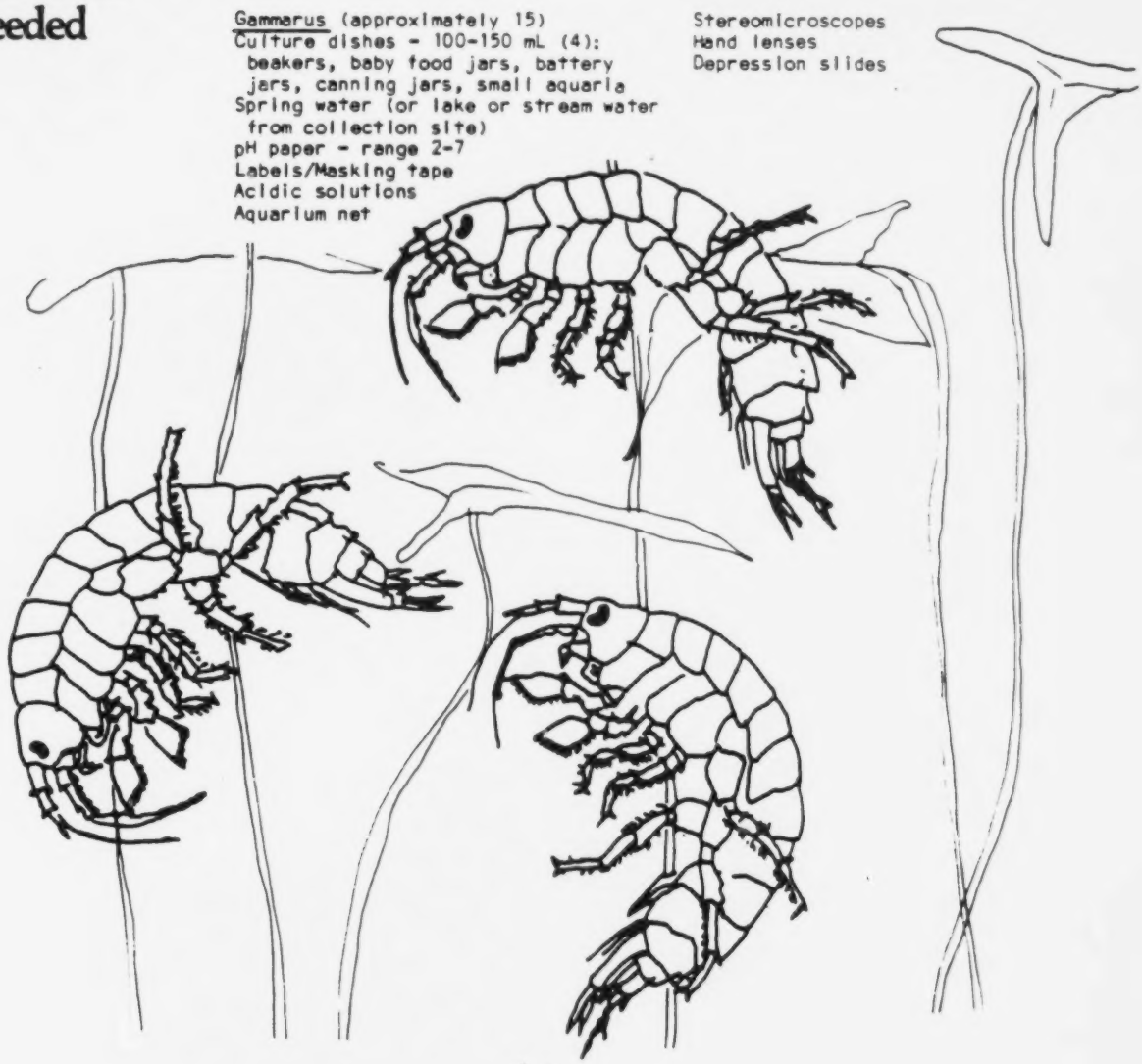
Materials needed

FOR EACH TEAM:

Gammarus (approximately 15)
Culture dishes - 100-150 mL (4):
beakers, baby food jars, battery jars, canning jars, small aquaria
Spring water (or lake or stream water from collection site)
pH paper - range 2-7
Labels/Masking tape
Acidic solutions
Aquarium net

OPTIONAL:

Stereomicroscopes
Hand lenses
Depression slides



ABOUT GAMMARUS

Gammarus are common freshwater crustaceans which live in permanent lakes, ponds and streams in northern temperate climates of North America and Eurasia. *Gammarus* is important as a fish food in many northern areas of the world.

You may know *Gammarus* as amphipods or "scud". *Gammarus* are very active acrobats: they swim, they jump, they crawl...they are almost always on the move unless they are sated by food. They are not easy to catch by hand and you will find a fine mesh fish net useful. In shallow pot holes, collecting with a net near the edges of the lake in spring often yields high numbers. Amphipods are also easily collected by washing aquatic plants over a mesh net (1-2 mm) or by gently scraping them from the vegetation into collecting jars.

Once you know where to look for them (in decaying vegetation, under stones and rocks in streams) scud are easy to collect. *Gammarus* are also quite easy to raise and maintain in the lab. *Gammarus* should be placed in at least 1 L water per 100 animals. A sand or gravel bottom will do. An aerator can be connected and bubbled, but not so strongly the animals cannot find footholds. They can be fed almost any standard fish food once a week (10.5 g/100 animals). They do very well in refrigerators because of their low metabolism.

Biological Science: Invitations to Discovery by the staff of the Biological Sciences Curriculum Study (1975, Holt, Rinehart and Winston, New York), contains information on how to raise *Gammarus*.

Teacher guidelines

1. Biological activity occurs optimally within a narrow range of environmental conditions. Species are well adapted to a surprisingly narrow range of environmental conditions and the ranges of tolerance to environmental conditions of a variety of species are not equal.

   At the extremes of environmental gradients are found lethal environments. These are the limits where physiological functioning is so reduced that the organism can no longer survive. Along an environmental gradient, biological activity may be divided into two convenient levels. There is a minimum level of individual maintenance. Above this level individuals can maintain themselves for long periods. Above the second level, the minimum population maintenance level, there is enough energy for reproduction so that the population can be maintained.

   This activity focuses student's attention on an animal's response to an environmental gradient -- conditions of varying pH. Students gain an understanding of concepts such as range and optimum.

2. To begin, tell students that they will be investigating the responses of *Gammarus* to various levels of pond acidification. Most students will probably not be familiar with *Gammarus* or scud, so show them the scud that you have collected/ purchased for this work.

   Have teams of students add 250-500 mL of spring water (or water in which *Gammarus* were collected) to a container. Add 2-3 *Gammarus* to the container. Give students ten to fifteen minutes of exploratory time with these animals. Students should make as detailed a sketch (labeled) of *Gammarus* as they can and observe their general behavior. Guide their observations by asking them questions such as:

   - Where do *Gammarus* spend most of their time in the container?
   - What percent of the scud's time is spent moving? At rest?
   - Do scud use all of their legs for swimming? How sure are you?
   - Which legs are used for climbing on solid surfaces?
   - What body parts do *Gammarus* use to achieve their fast, somewhat darting, movements?
   - What environmental factors are present?
   - What can you say about the preference *Gammarus* show for particular environmental factors?
   - Are *Gammarus* social organisms, that is, do they appear to prefer being together?
   - What do *Gammarus* do when they "bump" into each other?
   - Touch a *Gammarus* gently. Use a glass stirring rod or a pencil. How sensitive is *Gammarus* to touch?
   - Carefully watch one *Gammarus*. Can you predict where it will move next? Does it appear to move at random or does it move in a certain direction?

3. Tell your students that animals respond to many environmental factors, including chemicals. Ask them how they could find out how scud respond to solutions of varying acidity. List the materials available to them on the board. These are: 100-150 mL containers (4/team); acidic solutions (4); pH paper; Gammarus (15/team).

   As suggestions are made, ask questions which clarify intentions. Students may have to modify their suggestions based on the available equipment. It may be very useful to ask a few students to draw a rough sketch of the experiment on the board or to modify sketches until there is general agreement on the procedure.

4. Tell students that in any laboratory investigation in science, reliable results depend heavily on the identification and control of variables. In an experiment, investigators prefer to change or manipulate a variable and observe and measure changes in another - the resonding variable. Then, during the experiment, they try to keep all the other variables constant.

   Put these columns on the board: Manipulated Variable, Responding Variable, and Variables Held Constant. Ask students to describe the variables in this experiment.

   To guide this discussion, ask students these questions:

   - What variable is being changed or manipulated in a regular way in this investigation?
   - As the manipulated variable is changed what response are we going to look for? What measurement operation best meets the needs of the situation?

     Scientists prefer, when possible, to quantify responding variables. Students may, for example, mention "survival" as a possibility. What does this mean? -- How do you measure survival? Is it the length of time until organisms die? Is it the length of time during which half of the organisms die?

     You and/or your class may not want to kill Gammarus or, at least, you may want to minimize the possibility of their death for the purposes of this experiment. A student may suggest looking for evidence of a "change in behavior." Can this variable be quantified? If so, how?

     If this variable -- a change in behavior -- cannot be quantified, how is it to be recognized? The description must be accurate enough so that someone reading the laboratory procedures describing the experiment would be able to repeat it in the same manner. The person doing the experiment ought to be able to repeat it again. Anyone doing the experiment again ought to be able to obtain similar results.

     These are questions about terminating the experiment. The issue at hand is what the student investigators need to know in this experiment.

   - What are all the possible variables which might influence this experiment? Can they be controlled? Which ones cannot be controlled? What should be done about them? Will the variables that cannot be controlled have any influence on the outcomes? Can we tell?

5. Divide the class into teams of two or three and give them a copy of the Scud Experiment sheet. Before students conduct the experiment have them: 1) make a diagram of the experiment and label it, and 2) construct a data table. Then, let them complete the experiment.

6. After each team has conducted the experiment with their Gammarus, have the students return their animals to the storage container and the cleaned equipment to the appropriate place in your laboratory.

7. Place a number line on the board representing pH from 0 to 7. Using the data recorded in their laboratory sheet, tell students to place an X above the line that corresponds to the pH of the responding variable. The X's should be placed one above the other. Ask students what these numbers represent.

When this is completed, have student teams transform these data into a graph. The graph can be a bar graph (histogram) or a line graph. The x- and y-axis of the graph should be labeled and the graph should be given a descriptive title.

8. Ask one or two teams to place their graphs on the board and discuss them.

   - o Does another team have a different view of the data?
   - o Is there another way of representing the data?
   - o What do your tests indicate the optimum pH is? Is the optimum best thought of as a point or narrow range?
   - o What are the limits of pH range for the class experiments?
   - o If an early spring thaw produced melt water of pH 5, what might occur to the population of Gammarus in a stream? To a population of Gammarus in a lake into which this stream flows? pH 3?
   - o What behavioral cues indicated that the animals were in trouble?
   - o Does Gammarus appear to be an organism that might be useful as an indicator of the relative health of an aquatic ecosystem? Why?
   - o How would you change this experiment to improve it?
   - o What is another experiment that could be done to learn more about the effects of acid rain on Gammarus?

Biological Sciences Curriculum Study. 1975. Biological Science: Invitations to Discovery. Holt, Rinehart and Winston, Inc., New York. ("The Galloping Gammarus" - pp. 119-120; "How to Raise a Gammarus" - p. 128).

James G. Needham and Paul R. Needham. 1962. A Guide to the Study of Fresh Water Biology. Holden-Day, Inc., San Francisco.

George R. Reid. 1967. Pond Life: A Guide to Common Plants and Animals of North American Ponds and Lakes. Golden Nature Guide, Golden Press, New York.

STUDENT DATA SHEET

DATE _____

TEAM MEMBERS _____

Make a diagram of your experiment and label it.

Is the Gammarus holding jar/aquarium an appropriate experimental control in this investigation? Explain.

Should you take any measurements? What measurement(s), if any, should you record from the holding container? Explain.

Data Table

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Answer the following questions.

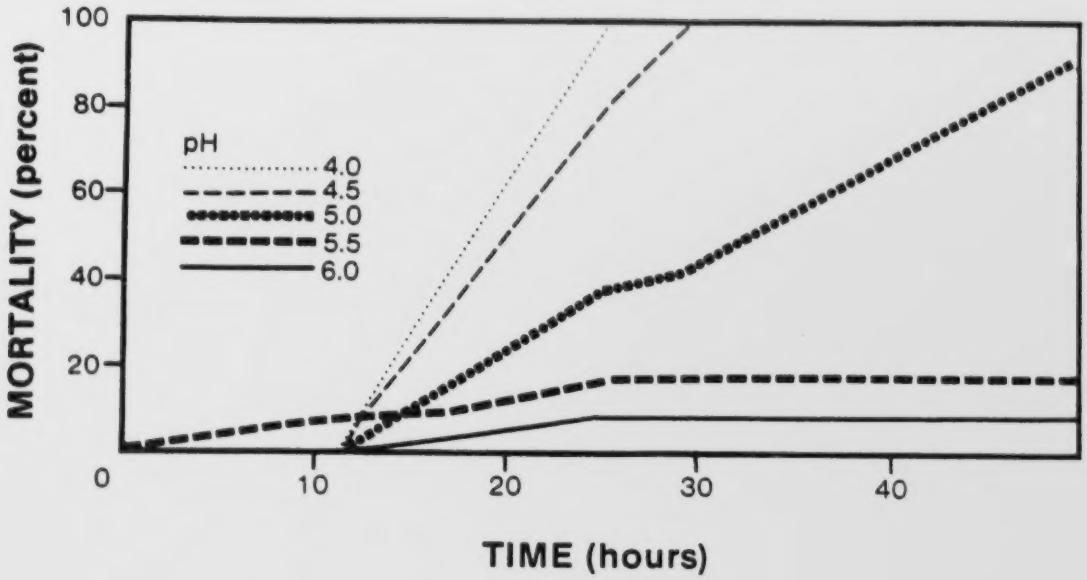

Figure 1. Percent mortality of gammarus adults exposed to indicated pH treatments in laboratory aquaria. Twenty adults, all over 1 cm long, were used in each treatment. From George R. Hendrey, Proceedings of the Action Seminar on Acid Precipitation, 1979.

In the graph above:

a. Which pH has the highest mortality?

b. Which pH has the lowest mortality?

c. For each pH what is the % mortality at 10 hours? 20 hours? 30 hours?

d. What would you predict the mortality of Gammarus to be if it were placed in a solution of pH 2? pH 1? Is there a need to check these by experiment?

e. At what point does pH appear to be a limiting factor for Gammarus?

A research scientist who reviewed this experiment wrote: "I personally have never liked short-term tests where I monitor deaths, since I feel I'm working in a range that is too drastic to extrapolate to environmental conditions."

She asked this question: "Do you think a fast test (short time period required to measure mortality) is indicative of what could happen in a long-term test at a less damaging pH?" Explain your answer.

Questions 1-3 refer to the graph below:

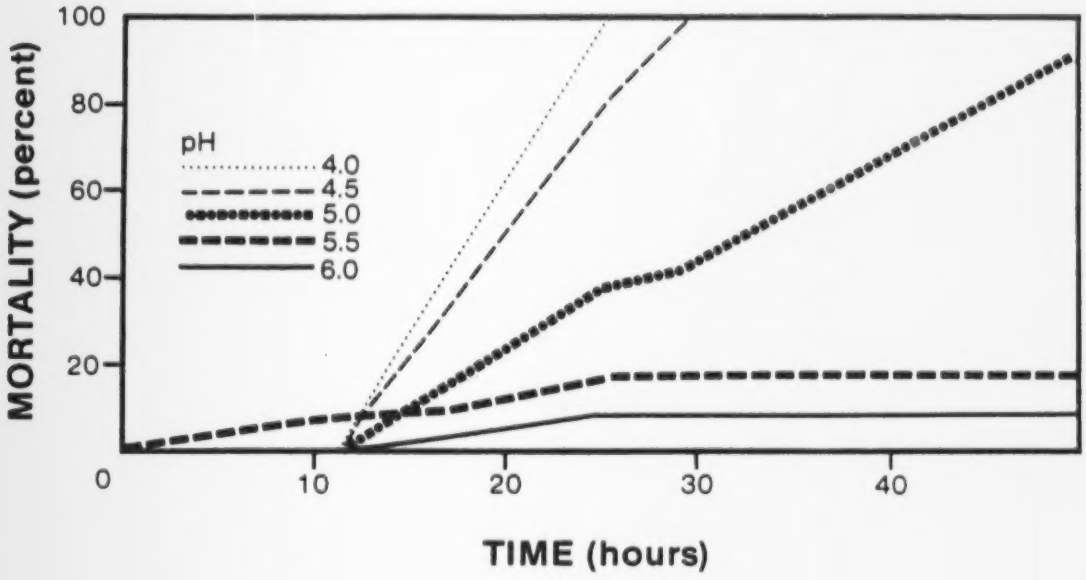

Figure 1. Percent mortality of gammarus adults exposed to indicated pH treatments in laboratory aquaria. Twenty adults, all over 1 cm long, were used in each treatment.

1. Which pH has the highest mortality?

A - 4.0
B - 4.5
C - 5.0
D - 6.0

2. For pH 5.0 what is the mortality at 20 hours?

A - 43%
B - 63%
C - 25%
D - 20%

3. At what point does pH appear to be a limiting factor for Gammarus?

A - pH 4.0
B - pH 6.0
C - pH 5.0
D - pH 5.5

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4. One advantage of using a long-term study of the effects of pH on Gammarus is:

A - More Gammarus will die.
B - Longer experiments always produce more accurate results.
C - You might gain information on how pH affects the Gammarus' total life cycle.
D - You might be able to find out how long it takes for all Gammarus to die.

5. A disadvantage of using a long-term study of the affects of pH on Gammarus is:

A - Gammarus don't live longer than a few hours even under ideal conditions.
B - It would be too expensive to set up and monitor a long experiment.
C - Gammarus is only one small species of animal. Acid rains effect on it is not very significant.
D - A long term experiment would be more difficult to control.

6. What is acid rain?

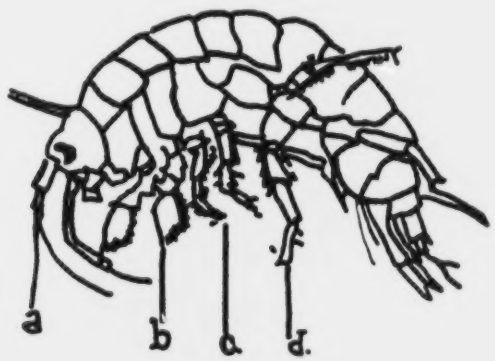
A - Rain which contains pollution harmful to life on earth.
B - Rain or other precipitation which is more acidic than "normal" rain.
C - Rain or other precipitation which has a pH of 7.0 or less.
D - Precipitation which contains emissions from power plants and automobiles.

7. The evidence gained from this lab suggests that animal life in lakes and streams depends on:

A - Many factors such as pH, sun, food, and temperature.
B - A water supply that is not too acidic.
C - An adequate supply of water.
D - So many things that they are impossible to control and identify.

8. Should we be at all concerned about the effect of acid rain on scud (Gammarus)?

A - Yes, because what happens to the scud affects the food web and indicates what could happen to other life.
B - No, because scud are unimportant in any food web and unimportant to any other plant or animal.
C - Yes, because if scud die from too much acid that means other plants and animals will suffer the same fate.
D - No, because scud reproduce so fast that an acid resistant variety would soon develop.



9. Which of the appendages on the scud drawing above are sense organs?

A - a.
B - b.
C - c.
D - d.

10. What is a variable?

A - Things that can change or cannot change.
B - Data which is graphed on x or y coordinates.
C - Things that must be controlled.
D - Independent and dependent variables.

11. Which of these variables must an experimenter be aware of in doing this experiment?

A - The temperature of the solutions.
B - How much light each solution receives.
C - The quality of the water.
D - All of these.

12. Which of the solutions acted as a control?

A - Spring water pH 6
B - Spring water + acid pH 5
C - Spring water + acid pH 4
D - Spring water + acid pH 3

13. How can you be sure that acid is the limiting factor in this experiment?

A - You can't, there are too many other things involved.
B - You must control the experiment so that acidity is the only variable.
C - By using only spring water you make sure acid controls the experiment.
D - By counting living Gammarus you can see the effect of acid rain.

14. If the experiment results showed that a pH of 4.0 or 5.0 was harmful to the Gammarus, would that be valid hypothesis or tentative explanation for another experiment?

A - Acidic water is harmful to animals.
B - Acid rain only harms certain animals.
C - If acidic water harms this animal then it might harm others.
D - If Gammarus are harmed then all water crustaceans will be harmed.

15. One possible inference based on the evidence from this experiment is:

A - Emissions from power plants and automobiles is a major cause of acid rain.
B - Acid rain could cause Gammarus to grow faster.
C - Acid rain could reduce life in certain lakes and streams.
D - Acid rain could damage all lakes and streams.

1-A, 2-C, 3-D, 4-C, 5-D, 6-B, 7-B, 8-A, 9-D, 10-A, 11-D, 12-A, 13-B, 14-C, 15-C

Life Sciences

(pH)(pH)ower

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Overview

Students become familiar with some characteristics of acids and bases. They learn how to use indicator papers to differentiate acids and bases, that acidities/alkalinities are often different, and that the pH of a solution represents its acidity or alkalinity.

Objectives

Through their experiences in this work, it is hoped that students will:

- o know certain properties of acids, bases, and neutral solutions.
- o demonstrate competency in the use of indicator papers.
- o systematically observe, record, and interpret data from an investigation.
- o recognize the need to acquire new skills.
- o interpret evidence critically.

Materials

Dropping bottles
Small beakers, baby food jars
Watchglasses or petri plates
Toothpicks
Spoons
Solutions, solids (powders). See Teacher Preparation.
Litmus paper - red, blue
Universal indicator paper, 1-11/2-10
Data Sheet: "Assigning pH"
Data Sheet: "Charting pH"

Teacher Preparation

1. Select at least a half-dozen substances for your students to test. Include both solids (powders) and solutions. Some items for solutions include: fruit juices; vinegar; milk; catsup; water solutions of acids and ranging pH from 2-10 (For water, pH 7, it would be necessary to boil it to drive off CO_2.); pond water; rainwater; snowmelt; ammonia (household); soaps/detergents; soft drinks; eggs.

   Some items for solids (powders) include: bicarbonate of soda; magnesium carbonate (in some indigestion tablets); calcium carbonate; magnesium hydroxide; citric acid; soaps/detergents; alka-seltzer; etc. Use instructional grade reagents.

   A set of numbered containers is needed for each group of six students. Make a master list of the solutions and their pH readings.

2. Laboratory safety is no accident. Emphasize safety and correct laboratory procedures. Instructors and students <u>should</u> wear eye protection. It is required in some states.

3. Indicator papers. A class can go through meters in a hurry. Either pre-cut small pieces or be explicit about the length of the test papers.

4. Optional Laboratory Introduction. A way to introduce this lesson is to provide each team of students an acid, a base, and water (Neutral). (You will have to boil it to eliminate the CO_2.) <u>and</u> 6 pieces of litmus paper (3 blue; 3 red). The solutions should have the same general appearance.

   Ask students, "What can you learn about these solutions by using these papers?" Remind them that the papers are the only materials they can use to examine the solution. Have them enter their observations in a data table similar to the one below.

LITMUS PAPER

TEST REACTIONS		
Sample	Blue	Red

Then ask students to establish criteria for testing solutions with litmus papers. After a discussion of the criteria, tell students that litmus (or indicator) paper is a simple test to determine whether solutions are acids, bases, or neutral. Discuss the following criteria:

If a solution causes litmus to change from blue to red with no change in the red litmus, it is an <u>acid</u>.

If a solution causes litmus to change from red to blue with no change in the blue litmus, it is a <u>base</u>.

If a solution causes no color change in blue or red litmus, it is <u>neutral</u>.

If you do this, you will probably want to modify the remainder of the activity.

Teacher Guidelines

1. Divide your class into laboratory work teams and give each a copy of "Assigning pH." Review the instructions carefully, as well as your laboratory procedures including laboratory safety.

2. When students have completed the work, ask some of the following kinds of questions:

   A. Read the names of the numbered solutions, ask students to record them in Table 1, and have them report the reactions to litmus paper.

      - Which are acids? Bases? Neutral solutions? Does everyone agree? (For differences ask, "how can we decide?" Then re-check the tests. Discuss possible sources of errors.)
      - Is the presence of water necessary for a substance to exhibit acid, base, or neutral characteristics?
      - Ask students to read some of the titles they chose for Table 1. What are the characteristics of a good, descriptive title for this table?

   B. Ask students to record the names of the numbered solutions in Table 2. Have them report the pH numbers.

      - How much variation is there in the outcomes for each solution? (For differences, ask "how can we decide?" Then re-check the tests.)
      - How accurate were the students findings?
      - Are there any patterns in the outcomes, e.g., errors and correct answers?
      - What could have caused some of the observed errors? (It is possible that students made methodological errors, e.g., used pH paper more than once or did not read the color chart immediately after dipping the pH paper or misread the color chart.)
      - Ask students to read some of their titles for Table 2. What are the characteristics of a good, descriptive title for this table? How does this title differ from the title for Table 1?

C. Acids, bases, and neutral solutions.

- In order to be an acid, what must a substance be? Base? Neutral? (For acids and bases there are two points which should emerge from this laboratory investigation: the substance must be in an aqueous solution and the substance must change litmus paper. Students will not know that substances ionize in solution. For neutral substances, the substance must be in an aqueous solution and the substance must not change litmus paper.)
- How could you define pH?
- What is a pH scale?
- If you want and if you used them in your work, put the formulas for two bases and two acids. Do not use organic chemicals. Ask students to look carefully at them. What do they seem to have in common? How are they different? Have students make a hypothesis of the characteristics that make a substance an acid or a base. (This discussion can add ideas about acids and bases.)
- What would happen to the pH of a solution if it were left uncovered (in a safe place) overnight? A weekend?
- How could you find out what would happen to the pH of a solution if it were diluted?
- To help students expand the ideas in this activity, give them a copy of "Charting pH." Ask them to answer the questions and use them as a basis for discussion. Ideas you can review include range, optimum, pH as an environmental factor to which organisms are exposed, and limiting factors.

Name: _____

Class: _____

ASSIGNING pH

The pH of a solution represents its acidity or alkalinity. In the laboratory you will find several solutions and solids in labeled containers. When you are conducting the tests, be sure you are careful to avoid contaminating these solutions and solids.

A. Place a drop or two of the solution or a small sample of the solid to be tested in a watchglass. Test each chemical with red and blue litmus paper by dipping it into the solution. Record all your observations in Table 1. Each solid is to be tested both as a solid and a solution. Add a drop or two of water to the solid and stir it with a toothpick. Carefully rinse and dry your watchglass. Repeat for each solution/solid.

When you are finished, classify the substances as acids, bases, or neutral. The litmus paper rules are:

- Acids cause blue litmus paper to change to red. They cause no change in red litmus paper.
- Bases cause red litmus paper to change to blue. They cause no change in blue litmus paper.
- Neutral solutions cause no changes in either red or blue litmus paper.

Then provide an appropriate title for the data table.

Table 1.

Compounds	Reaction to Litmus Paper	Acid/Base/Neutral
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

B. Acids and bases often differ in their level of acidity or alkalinity. The pH scale is a convenient way of expressing the concentration of different acids and bases. The pH scale ranges from 0-14. A substance of pH 1 is a very strong and hazardous acid (battery acid). A substance of pH 7 is neutral (pure water). A substance of pH 13 is a very strong and hazardous base (household lye).

In this investigation, you will test each compound as a solution with a different kind of pH test paper -- universal indicator paper. Place a drop or two of the solution to be tested in a watchglass. Dip a small piece of the pH test paper into the sample. Remove it. Immediately compare the color of the paper against the color chart. Read and record the pH. Do this twice for each compound. Use a fresh piece of universal indicator pH paper each time. Carefully rinse and dry your watchglass. Repeat for each solution.

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Table 2.

COMPOUND	Test 1	Test 2	Test 3
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Name: _____

Class: _____

CHARTING pH

SOURCE: George R. Hendry, "Acidification of Aquatic Ecosystems: Ecosystem Sensitivity and Biological Consequences." Presented to the Action Seminar on Acid Precipitation, Toronto, Canada, November 1-3, 1979.

1. What do the numbers on the horizontal axis represent? Indicate this on the pH scale.
2. Are there any pH values where only a few fish are found? What are they?
3. Are there pH values where no fish are found?
4. What is the optimum pH for fish? Indicate this on the pH scale.
5. What is the relationship between these data?
6. Place the substances you tested and which fit on the scale.

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Life Sciences

Response of bushbeans to simulated acid rain

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Overview

In this activity students investigate the effects of simulated acid rain on bush-bean plants. The activity will take two-to- three weeks from initiation to completion. The time requirements are roughly distributed as follows: 2 class periods to set up the investigation, part of each class period for 5-7 days to collect and record data, and 1-2 periods for students to present their findings.

Objectives

After completing this activity students will be able to:

- describe some effects of acid precipitation on plants.
- use scientific equipment to extend the range of human senses.
- describe effective variables to investigate in an experiment.
- appreciate the need to control variables and to use controls in investigations.
- identify and separate variables in approaching experiments.
- choose the most appropriate means of expressing observations.
- identify the essential steps in approaching a problem scientifically.
- distinguish observations which are relevant to the solution of a problem from those which are not.
- know conditions which promote changes in living things.
- describe changes in the physical and biological environment brought about by human activity.

Materials needed

FOR THE CLASS

The number of seeds and pots is based on a class size of 30-40 divided into 4 groups of 8-10 students.

Bush bean seeds, 60-65, Potting soil
2"-3" plastic or clay plant pots or peat pots or school lunchroom milk cartons, 30-40,
pH paper: narrow range, 2-7
Masking tape
Plant spray bottles - 500 mL, 6
Beakers, 6
Distilled water
Student Data Sheet - Bush Beans

OPTIONAL MATERIALS

Student Microscopes
Glass Slides
Cover Slips
Materials for starch test: test tubes, test tube holders, bunsen burners, alcohol, iodine

FOR THE SOLUTIONS

Rubber bulb pipettes/dropping bottles
Stirring rods
10% H_2SO_4
Cylinder(s) or graduated beaker(s) (The size is not important but laboratory glassware with a capacity greater than 250 mL will expedite measuring 500 mL quantities of solutions)
Spring water
6 Stock bottles/containers - At least 1000 mL. Any clean container with a cap and which has a dripless spout.

ACIDIC SOLUTIONS

See Appendix 1.

SEEDS

Soak bush bean seeds overnight in distilled water before planting.

Plant the bean seeds at least ten days before you plan to do the simulated acid rain experiment, two seeds/pot. Water with distilled water until two leaves are open. At this time the various treatments can begin.

Bush Beans

Have each group summarize their data and present their findings to the class.

Were there any variables which we did not include/consider which created trouble in our experiment? What problems did they cause?

What can you say about the potential impact on local crops? What do you know? What is the evidence? What evidence do you have? What evidence is missing?

- What are some of the effects of acid rain?
- How serious a problem is acid rain?
- Is acid rain more of a science-technology or a political-social problem?
- What do students predict the extent of this problem to be when they are 30 years old?

Tell students that they are going to investigate the effects of simulated acid rain on bush- bean plants.

Divide the class into 4 groups:

Groups A-1 and A-2 will water their plants at the soil surface. The solutions should not touch the leaves.

Groups B-1 and B-2 will water their plants with a spray bottle. The water will hit both the leaves and the soil.

Each group will have 6 plants. The solutions should range from pH 2-6. Pots should be labeled with the group number and a symbol or letter to represent the pH. One plant should be watered with distilled water. The amount of the solution used to water the plants will vary. It depends on the size and type of pots, type of potting soil, temperature of the room, etc.

Once established, the amount of water should not vary. As a guide, record how much water is needed during the germinating period to keep the soil evenly moist but not soggy.

You will want to discuss variables and operational variables with your class. The discussion should focus on controlling variables. Students should identify variables which may influence the system under investigation. Brainstorm a list. Then have students identify the variables which are manipulated, responding, or held constant for this experiment. Variables are discussed in more detail in Section A: Class Developed Experiment.

Each group, A-1, A-2, B-1, B-2, should prepare a table/tables for recording observations. A Student Data Sheet is included for their use or modification.

Have each group summarize their data and present their findings to the class.

Debrief the Experiment

Summarize the work with a class discussion on the effects of pH differences between soil-watered and leaf-watered plants, experimental procedure and control of variables.

What can we say for sure as a result of doing this experiment?

How much variability was there in the outcomes from group-to-group? What might help explain this?

In this experiment, how safe are we in assuming that artificial acid precipitation accounted for the differences? What is your reason for saying that? How else could this matter be viewed?

Was the sample large enough to rule out individual differences between plants?

As a result of this experiment, what can you say about the effects of acid precipitation on other plants such as trees (deciduous and conifers), lawns, radishes, lettuce, corn, soybeans, and other farm crops? How do you know?

If it was found that certain varieties of beans are more resistant to the effects of acid precipitation than others, do you think scientists should work hard on developing these species? What are your reasons?

Assume you are in a meeting where someone says to you: All this talk about acid precipitation and agriculture is crazy. No one knows for sure whether it has an effect on soybeans or not. What would you say?

If you were going to repeat the experiment with bush beans, how would you improve it?

Teacher guidelines

Experiments are used to ask questions of nature. Two approaches are presented, neither of which is mutually exclusive:

1. Class developed experiment, in which the teacher facilitates the design of the experiment and in which process skills are emphasized.
2. Class presented experiment, in which the teacher presents most of the experimental design.

Because communicating results of research is such an important skill in science, you may want students to make a written report. The form the report takes is not important. If you decide you would like to use a report, suggest an outline. Two possibilities are suggested:

FORMAT 1

Problem
Methods/Procedure
Data Analysis
Interpretation/Inferences

Have the class brainstorm a list of variables and list them on the board. When you have a good list discuss the different kinds of variables -- manipulated, responding, and variables held constant. The latter should not be called constant variables!

As you ask the following questions present the possibility of dividing the class into two different experimental groups. Each group would examine different manipulated and responding variables. Each group could be divided into small subgroups so that each experiment is replicated and also to provide all students as direct an experience as possible.

- Which variables are going to be the ones we change?
- Which ones will be the manipulated variables?
- Which ones will be the responding variables?
- Which ones are the variables held constant? Can we hold all these variables constant? What are some of the reasons?
- Can we afford to ignore some of the variables? Are any irrelevant? Are some of them so small in comparison to others that they can be neglected?

Define the variables operationally. In experiments, scientists try to get empirical. What are specific operations that can be performed to measure the variables -- manipulated and responding -- in which we are interested? How will the effect of the simulated acid precipitation be measured?

- Quantitatively
  Plant height
  Leaf size
  Leaf shape
  Number of branches
  Number of leaves
  Growth rate
  Lesions (spots) - number, percent leaf area injured, size
  Leaf margins and leaf tips - shriveled, dead
  Flowers per plant
  Pods per plant
  Pods, dry weight
  Stomate* guard cells: large, small
  Other

In some experiments, not all variables of interest can be quantified. When this is the case they must be carefully described. Both the investigator and other investigators must be able to recognize them. This insures that the experiment can be repeated in the same way again and again. It may be by the same investigator or someone else in another laboratory.

---

*Requires microscope

FORMAT 2

Hypothesis Investigated
Materials and Methods
Observations and Recorded Data
Conclusions

A. Class Developed Experiment.

Introduce the investigation phase of this activity by asking your students a question about the group of bean plants you are raising:

> The evidence that nitrogen and sulfur oxides released into the atmosphere from coal burning power plants, other industries and automobiles may react with atmospheric moisture to form acids is increasing. Average precipitation in the northeastern United States is now much more acid than natural rain water. This increased acidity in precipitation may have detrimental effects upon plants. One way to understand the extent of injury after exposure to acid rain in nature is to perform a laboratory experiment. To do that we have to ask a question of nature. One such question we might ask is:
>
> Will bush bean plants show some evidence of the possible effects of acid rain (grow more slowly or suffer more injuries) when exposed to different levels of artificial (simulated) acid rain?

Use the following outline to help students design an experiment to answer this question.

What are the variables?

Variables are the factors which may influence the behavior or the properties of the plant (or biological system).

- o pH or relative acidity of the simulated acid rain solutions
- o Time (hidden within the phrase "grow more slowly")
- o Method of adding the simulated rain, e.g., mist or directly to soil
- o Injury
- o Soil
- o Other

In an experiment one variable is changed (manipulated variable), another variable is observed for change (responding variable), and the remaining variables are held constant (kept the same). The latter are referred to as the variables held constant.

- o Qualitatively
  - Color
  - Growth characteristics: tall spindly, short spindly, short bushy, tall bushy, etc.
  - Root differences: descriptive
  - Starch production
  - Other

Be sure to ask students how the variables held constant are going to be held constant. It is not always possible to keep all these variables held constant. These should be identified and named. Room temperature may be this kind of variable. However, for all plants it will probably vary in the same way (direction) during the experiment.

Design the Experiment.

A test must be devised to determine the effect(s) of the manipulated variable on the responding variable. Some of the major decisions include: sample size (how many plants and how will we keep track of them); when the data will be collected (when to observe/measure the responding variable); and when to end the experiment (how long).

It may be very helpful to diagram the experiment on the board and/or to have students make a rough diagram of the procedures.

How will we record the data?
- Notes
- Design tables for organizing data interpretations
- Use histograms (graphs), where appropriate, to show results

Discuss a suitable table before data collection begins. You may want to recommend appropriate tables. Individual plants -- each is a data source -- will have to be identified. You might decide to record only initial conditions and final conditions, e.g., plant height. The difference between the two would provide comparisons of growth rates.

Graphs are extraordinarily valuable because of the way they can help expose patterns visually. This is one of the reasons why tabular data is often converted to graphical form. If plant growth as measured by height were a variable of interest, a class histogram, comparing pH differences, could be constructed. Plant height would be recorded on the x-axis and frequency, number of plants at each height, would be recorded on the y-axis. The different conditions of pH, would have to be shown by symbols, e.g., X's, O's, O's, O's, O's.

Lead a class discussion to share results and to integrate activity results. If the class was divided into separate work groups, subgroups which did the same experiment could make a composite graph and report their results.

What is the relationship between the manipulated and the responding variable?
How good is our evidence? What can you say in defense of your view?
How much variability is there in the evidence we collected?

Student data sheet Bush beans

Name: _____

Group #: _____

Observation Type: _____

Day After Starting \ pH						
1						
2						
3						
4						
5						
6						
7						

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Life Sciences

The effects of simulated acid rain on conifer seedlings

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"The effects of simulated acid rain on the growth of seedlings has been studied by several ingestigators. (In one study, there was) no effect found on the growth of yellow-birth seedlings exposed to mist with pH 3 and above. Mist with pH 2.3 reduced the growth of the seedling. (Simulated rain of pH 5.4, 4.3, and 2.5 (has been applied) to rooted cuttings of two clones of Norway spruce. (Investigators) found a slight increase in dry matter production with increasing acidity of the rain. The increase was, however, not statistically significant. In another study (researchers) applied rain of pH 5.4 and 2.5 to cuttings of seven clones of Norway spruce grown at three different temperatures. In this case they found an increase in growth by the acid treatment. The growth effect appeared to be caused by increased N uptake indicating increased mineralization of N in the soil."

- Acid Precipitation - Effects on Forest and Fish by Lars N. Overrein, Hans Martin Seip, and Arne Tollan, 1980, p. 136.

"While scientists in Europe and North America do not agree on the cause-effect relationship between acid deposition and forest decline nor the pathways by which acid deposition might cause declines, certain common observations appear in the scientific literature on both continents:

- o Conifer mortality has been observed over an extensive geographic area and in a wide variety of soils having substantially different properties.
- o Drought or particularly warm, dry summers are associated with a loss of vigor that appears to be related to decline.
- o Chemical data for the roots of declining spruce and fir suggest the possibility of a calcium deficiency in root tissue.
- o On both continents, the foliage of declining trees has 10% more sulfur than the foliage of healthy trees.
- o The severity of damage increases with increasing elevation.

- Acid Deposition and Forest Decline by Sherman Hasbrouck, 1984.

Overview

The effects of acid rain on young conifers are examined by stimulating natural conditions in the laboratory and the relationship between survival of red pine seedlings and varying levels of acidity is explored.

Two different approaches to the work are described. In the first option, the activity begins with a question and students are asked to participate in the solution. In the second option, students read the description of a fact-finding experiment done by high school biology students. This framework can be used to repeat the experiment or to modify and improve the experiment or to find out whether artificial acid rain would have the same effect on a different species of conifer seedlings.

Objectives

AFTER THIS ACTIVITY STUDENTS SHOULD BE ABLE TO:

- o identify manipulated variables, responding variables and variables held constant in an investigation.
- o identify effective controls for testing hypotheses.
- o devise a test to determine the effects of a manipulated variable on a responding variable.
- o construct a data table for recording experimental observations.
- o choose the most appropriate means of expressing observations.
- o critically examine the results of their own and others' work.
- o report data from an experiment.
- o describe the potential effects of acid rain on Red Pine seedlings.

Materials needed

OPTION 1

FOR A CLASS OF 30:

Conifer seedlings -- white or red or jack pine. Approximately 100. Double the number if H_2SO_4 and HNO_3 acidic solutions are to be compared.

Fine sand and perlite mixture or a light soil
pH paper, narrow range
Plant pots
Distilled water/aged tap water
Graduate cylinders
Beakers
Conifer Plant Watch form

OPTIONAL:

pH meter
Soil pH kit
Soil moisture meter

ACIDIC SOLUTIONS

Stock acid solutions (reagent grade sulfuric and/or nitric) of pH $\geq$ 5.6 ("normal" rain); pH 4.7 (acid rain); and pH 4.0 (very acid rain).

OPTION 2

FOR A CLASS OF 30:

Conifer Seedlings -- white or red or jack pine. Approximately 100. In the experiment described, 384 red pine seedlings were used.
Planting medium
Greenhouse planters - plastic
Greenhouse flats
Plant mobile (Jewel 308/3081)
Wet and dry bulb thermometers - 2
Thermometers - 2
Masonite
Plastic sheeting, clear
Timer, light
pH meter
pH paper
Soil pH meter
Soil moisture meter
Spray bottles - 8
Conifer Plant Watch form
Conifer Research: Class Report
Conifer Research: Class Data

ACIDIC SOLUTIONS

pH 2.5, pH 3.0, pH 3.5, pH 4.0, pH 4.5, pH 5.0, and 5.6. Prepared by adding sulfuric acid to distilled water.

ADVANCE PREPARATION

At least two days before you expect the conifer seedlings to arrive, if you do not have distilled water, age containers of tap water. Be sure to check the pH. You may have to boil and cool it before you use it, especially if you are interested in using this water at pH 7. Stations for soil, planters and seedlings should be set up.

Departments of Natural Resources or district foresters may be able to supply conifer seedlings and help for experimental purposes. The request could be accompanied with the research proposal you and your class develop. If you live in an area rich in conifers you can dig your own seedlings.

Teacher guidelines

OPTION 1

1. Pollution is a result of the addition of substances to ecosystems in quantities large enough to harm organisms. The substances are referred to as pollutants. Pollutants are not always visible and tests are often necessary to determine their presence as well as their effects.

   Introduce this lesson by asking students to name substances that are or that might become pollutants and list these on the board under a column labeled POLLUTANTS. Then, ask students for evidence of change/interaction caused by pollutants. List these under a column labeled EFFECTS. Focus the answers, as much as possible, on the effects of organisms. Some questions which will help guide this discussion:

   - What have/can you observe happening?
   - Are the changes permanent or temporary? How do you know?
   - Are there any forms of energy connected with the change? If so, what are they?
   - Is the effect local or widespread?
   - What kinds of effects did/might the pollutants have on animals? On plants? On humans? On the environment?
   - Do all things change?
   - How do we recognize change? Harmful change?
   - What are some observations you could make to observe harmful change? What observations are relevant?
   - Is the change you described a physical or chemical change? What is the difference?
   - What is being done to resolve these problems? What are the benefits? Risks? What is the cost?
   - What do you predict for some of these problems 25 years from now?

2. This exploration is designed to help students investigate and understand the effects of too much of what once was a naturally occurring substance (acid rain) on conifers.

   Decide whether you want students to compare the effects of two different kinds of simulated acid rain: H_2SO_4 and HNO_3. For such a comparative study, you will need twice as many conifer seedlings. Because acid rain consists of both SO_x and NO_x, you may want students to work with both variables.

TEACHER NOTE

The "naturalness" of acid rain needs some discussion and clarification. This is a point of contention between those who would do nothing about acid rain ("less action and more research") and those who would ("more research and more action").

It is thought that the pH of "pure" rain is controlled by carbonic acid (H_2SO_4), resulting from atmospheric CO_2 in solution. The resulting pH would be near 5.6. However, when alkaline dust and ocean spray are added, the pH of precipitation must be higher than pH 5.6. It may be around 7.0. There is not a way to test this theory because of the severity of global air pollution. In general, the acids of concern in acid rain are the result of human combustion of fossil fuels from industrial processes, power plants and transportation. These are referred to as anthropogenic sources, and have been added by human activities to natural rain.

It is thought that under unpolluted conditions, the pH of rain would vary locally. In geographically unbuffered areas, small releases (small compared to human caused releases) from volcanic activity and microbial metabolic processes would cause a slightly lower natural pH than 5.6, the theoretical level. In places rich in calcareous materials, the action of wind on soil and dust would cause pH levels higher than this.

It is now very clear from a wide variety of studies that precipitation is far more acid than the rain of an unpolluted, non-industrialized environment, especially in regions where prevailing winds carry oxides of sulfur and nitrogen from heavily industrialized areas.

3. A way to introduce the work is to ask students a simple question about a group of conifer seedlings that you have been growing for several weeks (approximately a month). The plants should already be potted and have been watered with distilled water/aged tap water (pH > 6.0) before treatments. The time is for acclimatization. You should have a reserve supply of plants to replace any that die.

   You may want to start the work when the conifer seedlings arrive. If so, see 3b below.

A question you can ask is: "How does acid rain of varying pH (and source, if you choose to use two different mineral acids) affect the growth of conifer seedlings?"

When the conifer seedlings arrive you should have distribution stations for soil, planters, etc. Extra seedlings should be planted for absent students and for a reserve supply of plants. Divide the class into small groups of about five. Each group will be responsible for 10-12 plants (20 if two different acid solutions are used).

Tell students that these plants are going to be used in a research project on acid rain several weeks from now. However, before the work can begin, the plants must be given a period to acclimatize. This period of four weeks will provide students with an opportunity to see how the seedlings grow and develop. Students will also become familiar with their watering requirements.

These plants will be watered with distilled water and should be kept moist. Dechlorinated tap water can be used. The pH should be greater than 5.6. The plants should be placed in an area of natural or artificial light (a special light for growing plants) and monitored carefully.

Students should keep records during the acclimatization period. Distribute Conifer Plant Watch forms. Brainstorm a list of observation possibilities, e.g., height, evidence of growth, color, needle discoloration, needle loss, mortality, watering schedule (when, amounts), etc. Students should add extra sheets as required. Suggest that detailed records be kept on individual plants and that general summary statements be written for each of the four weeks of conifer seedling acclimatization.

The initial set-up should not take longer than half a period, with four weeks of maintenance and observations before the experiment begins. This should only take a few minutes every other day. Students can rotate this responsibility.

Have students formulate a testable hypothesis to this question, e.g., at pH's less than "normal" rain the growth rate of conifer seedlings will be adversely affected, or conifer seedlings will not be adversely affected until the pH exceeds one value on the pH scale below that of natural rain, or the ideal pH for conifer growth will be that of natural rain. This is only one of many possible testable hypotheses. It would be useful to brainstorm some possibilities and then decide on a hypothesis. Once this is done it should be left on the board for everyone to see.

4. List the materials available on the board: pH solutions: $\geq$ 5.5, pH 4.7, pH 4.0; distilled water or aged tapwater; conifer seedlings; graduated cylinders; beakers; pH paper. If you have a plant mobile equipped with space for growing plants and want to use it, list it.

   While the materials listing will be of most use during the actual design of the experiment, the list will be helpful in considering variables which influence the investigation. The materials also represent some "givens" which serve to limit, define and constrain the possibilities.

5. Once an appropriate hypothesis has been stated, variables must then be identified. Put the word VARIABLES on the board. Have students brainstorm the:

   - o variables which may influence the biological system under study;
   - o manipulated variable - the variable that will be changed in some way during the experiment (Label MV);
   - o responding variable - the variable that will be used to watch for or monitor changes (Label RV) in response to the manipulated variable;
   - o variables held constant - Label the variables you can think of to be kept the same during the work (Label VHC).

6. Have students operationally define the manipulated variable and the responding variable so that these can be measured.

7. Divide the class into small groups and ask them to design an experiment based on the information they have collected. As they work use these kinds of questions to keep them focused on the parameters of the design:

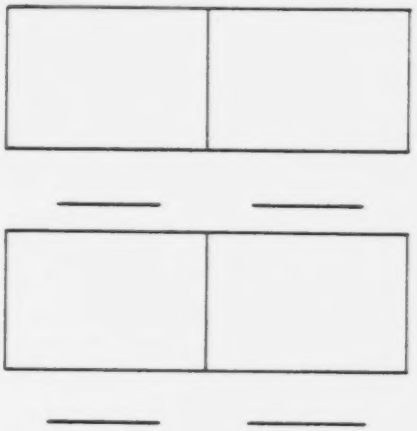
   - o How many and which pH measurements will be tested?

- How long should the seedlings be subjected to the experimental treatments? How do you decide when to terminate the experiment?
- How will the plants be distributed among the class? There are 3 pH solutions: pH 4.0; pH 4.7; pH 5.6, and distilled water (What is this for?).
- How many plants will be used? How will they be divided?
- When will the data be collected?
- How will we organize the class to conduct this experiment to avoid chaos and to ensure quality of results? Should research teams be in charge of particular pH levels/solutions? Should each team have a representative sample of solutions?
- How will the plants be marked?
- What records will we keep?
- Are we going to collect data on room temperature? Room relative humidity? Soil pH? Soil moisture? When? How often?
- How will we organize our observations into tables? What will a data observation sheet look like?

Have one (or more) of the teams present an experimental design, clarify it and seek agreement on it. Encourage students to be critical, e.g.,

- Is the proposed design an appropriate test of the hypothesis?
- Is the plan simple and straightforward or does it create unnecessary confusion? Where? What can be done to modify and improve the plan?
- Does everyone understand what data are being collected? If, for example, one student is the only representative of a team, will s/he know what to do?
- Will the design provide us enough data? Is the sample size large enough?
- Is there anyone who has a different viewpoint? What is your suggestion?
- What are the laboratory safety considerations in this experiment?
- How are we going to ensure that this is a safe experiment?
- What should be labeled? What kinds of labels? How should materials be labeled?

If students have trouble thinking of a way to use the materials, first, encourage them to make simple diagramatic sketches of the work. If students continue to experience difficulty, draw a rough diagram on the board and use it to talk with them about the experiment. One possibility, if one acid is used, is the following:



As students ask questions and discuss the work, label the cells to reflect pH, distribution of plants, the way the effort is to be divided among the class, etc. The cells can be divided to represent replications (groups). Finally, the experimental design can be redrawn to more accurately represent the actual experimental design.

You may find it useful for the class to have a copy of the final experimental design and procedures. It may be valuable to make copies of the table which will be used to record and organize the observational data. Copies of the sheets describing the design and procedures and the data sheets could be kept near the experiment.

8. After the experiment is underway the work is primarily maintenance and data recording. The soil must be checked regularly and watered when necessary. The plant response is to be, inasmuch as possible, differences in acidity; not to water deficiency or to excessive water.

   If possible, take a few minutes each week to discuss the experiment.

9. When the experiment is completed help students prepare class graphs from the tabular data collected. A histogram may be an appropriate way to represent the data. Explain to students that this is a graph that shows how many plants exhibited some value of the variable measured in this experience.

   - What should be measured on the x-axis?
   - What should be measured on the y-axis?

- How should each axis be labeled?
- If two different mineral acids were used, how can the data be represented on the same graph?

Have teams record their data on a class histogram. Use the board or a large sheet of paper. Discuss this graphical display with the class. Use the following kinds of questions:

- What inferences can we make?
- What evidence can you offer in defense of your view? Where did it come from?
- How safe are we, in this experiment, in assuming that pH accounted for the differences observed?
- If two different acids were used to prepare pH solutions, ask whether the results are similar or different from one another. What inferences can you make?
- Are any other interpretations possible? If no, what are the reasons? If yes, what one(s)? If someone wanted to contradict your view, what could s/he say?

Be sure to ask about the appropriateness of a histogram for displaying these data. It may be appropriate but there may be other graphical ways of representing the data, for example, line graphs. Have students make a graph; label the x-axis time and survivors on the y-axis.

- Do these data have to be plotted on separate graphs, one for each solution, or can they be plotted on the same graph?
- What does this graph reveal about the experiment that the histogram does not, if anything?
- Do these graphs suggest anything about whether the experiment was too long or too short? What?

Have students change the y-axis to mortality.

- Do these data have to be plotted on separate graphs, one for each solution, or can they be plotted on the same graph?
- What does this graph reveal about the experiment that the histogram does not, if anything?
- Do these graphs suggest anything about whether the experiment was too long or too short? What?
- What is the difference between the survivorship and mortality curves?

Draw a graph on the board. Label the x-axis, pH, and the y-axis, survival (percent). Ask student to help you plot the data. Draw another graph on the board and label the x-axis, pH, and the y-axis, mortality (percent). Ask students to help you plot the data. Ask a student to draw a line which accurately represents the data.

- What hypothesis can you make about the relationship between increasing acidity and survival? Mortality?
- What differences were there in the behavior of the experimental and control seedlings? What could have caused these differences?
- What differences were there in the behavior of the H_2SO_4 treated seedlings and the HNO_3 treated seedlings?
- How could you find out whether a forest ecosystem was receiving a harmful excess of acid precipitation?
- Based on these data why is acid rain considered "hazardous" to the health of ecosystems?
- Does this experiment suggest a cause-effect relationship between exposure to acid rain? What are the reasons for your answer?
- In addition to pH, what are some of the variables which might have influenced the outcomes of this experiment? Which are most important? Which can we choose to disregard? What are some of your reasons?

How can acid rain be harmful even though it occurs naturally? (This is a good opportunity to review the influence of humans on the chemical climate of the earth.) We will never be able to know the pH of naturally occurring acid precipitation on a world-wide basis. Data are not available that allow a baseline for precipitation acidity to be set. However, some strong inferences can be made that it is increasing. For example, sulfate deposits have increased coincidentally with the beginning of the industrial age in Europe.

Acid precipitation has been a source of sporadic scientific curiosity since it was first described by Angus Smith in 1852. It was not until the mid-1950s that acid rain began to be understood as a widespread problem. It was found in areas distant from its anthropogenic sources. Its geography included, at first, rural areas, then acid rain was found to be a transboundary pollution problem encompassing a few states/nations. Today, it is understood as including both very large geographic regions of the earth as well as the earth itself. Scientific evidence is still accumulating and acid precipation has become a matter of public interest and a major issue of public policy.

- Based on this experiment, what evidence do you have that acid rain is a pollutant?
- Do the class data indicate an optimum pH for conifer seedlings?
- Do the conifer seedlings show evidence of variation in the way they responded? How do you know?
- What does the horizontal axis measure?
- What does the vertical axis measure?
- Can you make a hypothesis about the relationship between pH and survival of the seedlings?
- Can you use these data to predict what will happen if acid precipation problems continue to increase? How sure are you?
- What recommendations for the control of acid rain would you make based on these data?
- How do you think you could become better informed about issues related to acid rain?
- If you conducted this experiment outdoors what would you expect to happen? What hypothesis would you make?
- What is an additional experiment that could be done to learn more about the effects of acid rain on conifers?
- How could you improve this experiment to learn more about the effects of acid rain?
- What is being done to resolve problems from acid rain?
- What are we going to do with the remaining conifer seedlings?

OPTION 2

TEACHER NOTES

Students have few opportunities in school to read descriptions of original work done by student in other schools and to consider repeating/varying it. The experiment described in the Student Conifer Research Report was a fact finding experiment. The student data are found in the Appendix.

Your students have an opportunity to conduct a fact finding experiment of their own in a framework of previous knowledge. They can repeat the experiment or modify and improve it or find out whether responses from other conifer seedlings are the same. They can compare their data with data from another experiment, interpret and explain the results.

CAUTION

In the total school safety program, responsibility in the classroom and laboratory is a shared one between the teacher and students. Students should be expected to develop an acceptance of their responsibility for safety in biology laboratory investigations. You may want to make one modification in the work. In the experiment aerosol sprays were used to deliver acidic solutions to the conifer seedlings. If used, appropriate laboratory procedures must be developed and followed. This includes eye protection/face shields and respiratory protection. The acidic solutions must be handled with care at all times no matter how the simulated rain is delivered.

1. Give each student a copy of the Conifer Research Report form and review it with them. This is a copy of part of a report done by a class. (A teacher and 46 high school biology students). Allow about 10 minutes for students to read the report and then lead a class discussion. Use these questions to guide the discussion:

   - What do you already know about the material described in this report?
   - What questions do you have about the experimental procedure?
   - What are the variables in this experiment?
   - What was the variable the experimenters manipulated?
   - What are the responding variables? Which of these variables is the most easily measured (quanitited)? The least easily measured?

- What are some ways the less quantified variables could be measured? Are any of the variables not quantifiable? If you used such a variable, describe a way that it could be recognized. (This kind of description is important for many reasons; one of the main ones is that over the course of an experiment, the investigator must be able to constantly perform such observations in the same manner. Furthermore, similar results must be obtainable by all the researchers in such an investigation.)
- What are the variables the research team held constant?
- What was the purpose of the control groups? What treatment did they receive?
- Is the description clear enough so that you could repeat the experiment? What is not clear? What can we do to clarity it?
- How would you modify this experiment to improve it?
- If this work is to be repeated is it necessary to use all the pH solutions? What is your evidence? What assumptions are you making? If fewer acidic solutions are used is it still a "fair" test?
- What was the hypothesis in this experiment? Write the hypothesis suggested on the board. What data would support the hypothesis? What data would not support the hypothesis?
- Show students a copy of Figure 1. What do you infer from these data? Do the data support the hypothesis?
- Do red pine seedlings have a narrow or wide tolerance range to different levels of acidification? What is your evidence?
- Which of these three experiments would you like to perform: 1) repeat the experiment; 2) modify/improve the experiment; or 3) repeat the experiment with a different species of conifer? What are your reasons?
- What are the laboratory safety considerations in this experiment?
- How are we going to ensure that this is a safe experiment?
- What should be labeled? What kinds of labels? How should materials be labeled?

2. Divide your class into small research groups. Develop a list of procedures for carrying out the experiment. Put the list of materials available on the board. Some questions to guide this discussion are found in Option 1.

   Have a few groups report their procedures and develop a master procedures list and do the experiment.

3. When the experimental work is completed transform the data into tables and graphs. To begin with, use the formats found in the Conifer Research: Class Data forms. You may want to devise your own graphs.

4. Once the tables and graphs have been prepared ask some questions about the two sets of data. Make overheads of the Conifer Research: Class Data. Some questions which will help guide this discussion:

   - Table 1. What was the range of soil pH during their study? In our study? How are the data similar? Different? If different, is this a variable that might have influenced the experiment? Can we choose to ignore this variable? On what basis?
   - Table 1. Upon completion of the experiment, what was the range of soil pH in their study? In our study? How are the data similar? Different?
   - What are some other things you notice about the data in Table 1? Do your data show a similar or different pattern?
   - Table 2. How many trees died in their study? What is the mortality expressed in percent? How does this compare with our study?
   - Table 2. What is the range of the percent mortality in their study? How does it compare with our data?
   - Figure 1. In your own words, what is the relationship between the pH of simulated acid precipitation and mortality rates? Do our data show a similar or different relationship?
   - Figures 2 and 3. What do you notice about these data? What is the range? What month shows the greatest increase in mortality? Do your data show similar relationships? Are <u>both</u> sets of data -- mortality and survivorship curves -- necessary in a report on this investigation? Why or why not?
   - What can you say about the pH of rainfall and its effects on two different conifer species?

5. Conclude the activity with a general discussion of the investigation. Use some of the questions from Option 1.

Resources

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1872. Air and Rain. Longmans, Green, London.

CONIFER PLANT MATCH

Team Members: _____

Date conifers planted: _____

_____

Records for:

WEEK ONE

WEEK TWO

WEEK THREE

WEEK FOUR

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CONIFER RESEARCH: CLASS REPORT

I. Problem Investigated: What is the relationship between rainwater of different acidity and the survival of conifer seedlings.

II. Procedure Description: A total of 384 Red Pine seedlings, approximately five months old, was obtained from the state DNR nursery. The seedlings arrived, packed in peat moss, during the first week of October, 1982. Seedlings were sorted into eight groups of four dozen each for transplanting.

The planting medimum for all trees consisted of a uniform mixture of one-third peat moss, one-third soil (from the school greenhouse) and one-third selicon sand. The seedlings were immediately transplanted into 4x6x2-inch plastic greenhouse planters with bottom drains. Each planter contained one dozen, evenly spaced trees.

Planters were placed in 10x14-inch flats, four planters per flat and set up in a modified Plant Mobile (Jewel, 308/3081). Masonite partitions were installed between flats to prevent contamination by acidified rain from adjoining flats.

The plant mobile was further modified by sealing its back, sides and top with plastic sheeting and attaching a movable drop plastic front panel (Figure 1). This was done to control humidity and lessen the chances of outside contamination. The mobile was fitted with two, 40-watt Gro-lux fluorescent light tubes and two 40-watt incandescent light bulbs per level. Wet and dry bulb thermometers were mounted inside for monitoring relative humidity. A separate thermometer was also mounted inside for monitoring temperatures.

The seedlings were placed approximately twelve inches from lights and the lights were electrically timed: 12 hours on and 12 hours off. All seedlings were watered with distilled water and allowed to recover from shipment and transplanting for a period of four weeks.

Stock acid solutions of pH 2.5, 3.0, 3.5, 4.0, 4.5, 5.0 and 5.6 were prepared by adding sulfuric acid to distilled water. pH was measured with narrow range pH paper and a calibrated Beckman Zeromatic II pH Meter.

After the recovery period, flats and planters were separated into experimental and control groups. Each experimental group consisted of four dozen trees. Two control groups, were designated, one at each level. Forty-eight trees were assigned to each.

Application of simulated acid rain began on November 5, 1982. Spritzers on one quart plastic spray bottles were adjusted so that each full sprtiz delivered one milliliter of spray.

Application of simulated rainfall was made on a random basis but it was somewhat determined by soil moisture conditions. Consistent, uniform watering was avoided. Periods between applications and amount of moisture applied were varied to more closely resemble natural conditions. During each watering, artificial rain amount were the same for all study and control groups. Only the exception of pH levels. Soil moisture levels were monitored on a Monday, Wednesday, Friday basis throughout the study using a calibrated AMI Soil Moisture Meter.

Soil pH was monitored weekly using an AMI Instamatic Soil pH Meter. Initial and final soil pH's were also tested using a LaMotte Soil Test Kit.

Weekly observations were made of all trees and records were kept on needle damage, discoloration, loss and seedling mortality.

Final soil moisture, soil pH and tree observations were made on April 1, 1983.

Table 1. - Monthly Soil pH Readings of Control and Study Groups.

	Date					
	11/4	12/3	1/5	2/2	3/1	4/1
Top Control	6.7	6.5	6.2	6.4	6.4	6.6
pH 5.0	6.7	6.6	6.6	6.4	6.5	6.6
pH 4.5	6.7	6.7	6.6	6.7	6.7	6.7
pH 4.0	6.7	6.7	6.7	6.8	6.7	6.8
Bottom Control	6.7	6.4	6.4	6.5	6.5	6.7
pH 3.5	6.7	6.8	6.8	6.7	6.7	6.6
pH 3.0	6.7	6.8	7.0	6.8	6.6	6.6
pH 2.5	6.7	6.8	7.1	6.9	6.7	6.6

Table 2. Number of Survivors at the Beginning of Each Month of Study for Control and Study Groups

	Date						
	11/4	12/3	1/5	2/2	3/1	4/1	% Total
Top Control	48	42	38	29	26	25	52
pH 5.0	48	35	33	25	14	11	23
pH 4.5	48	43	40	36	11	8	17
pH 4.0	48	44	37	31	16	15	31
Bottom Control	48	47	45	43	29	29	60
pH 3.5	48	46	38	32	6	6	13
pH 3.0	48	46	33	22	0	0	0
pH 2.5	48	46	38	32	1	0	0

Conifer_____: Class Data

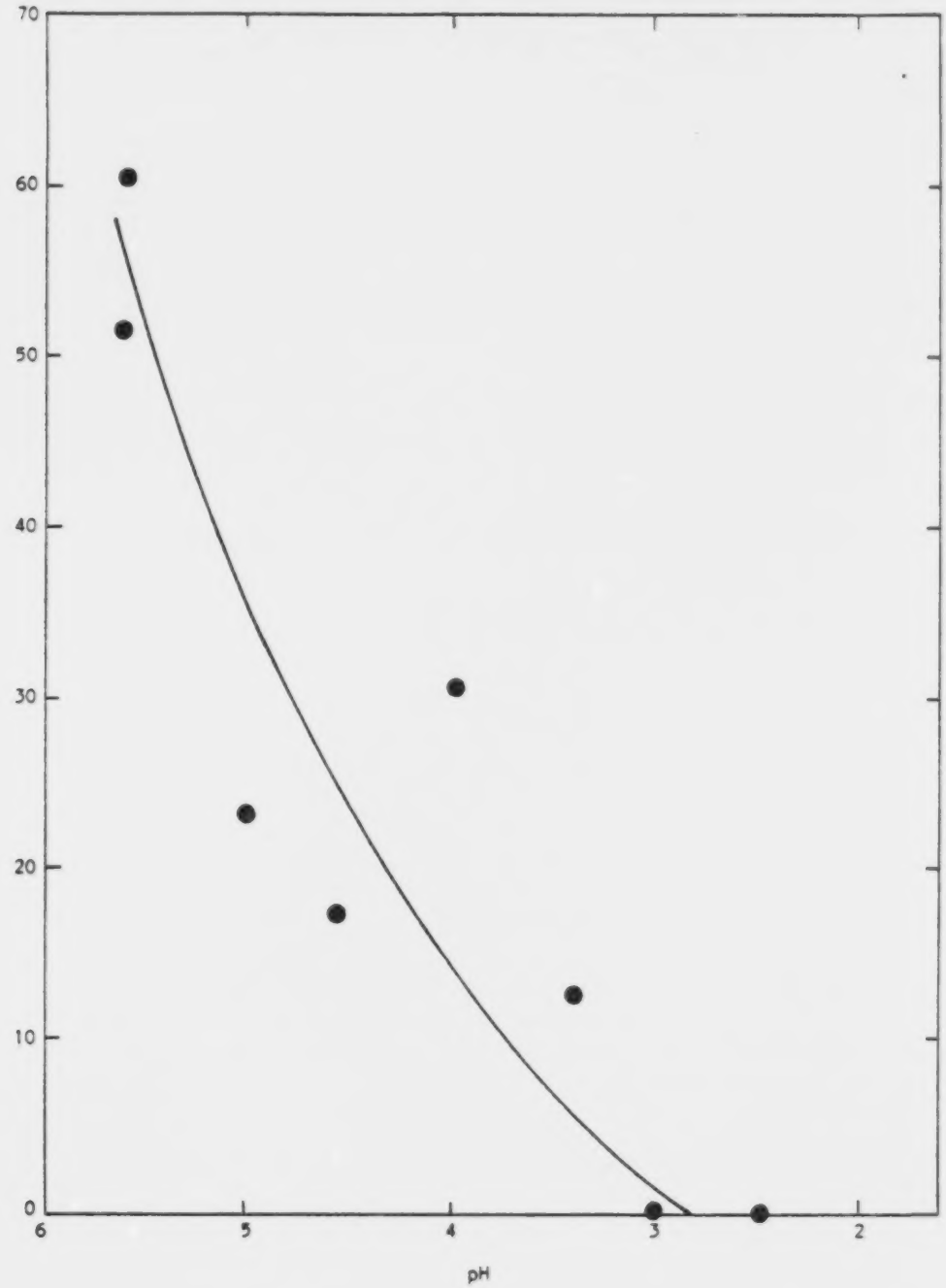

Figure 1. Effect of simulated acid rain on survival of red pine seedlings.

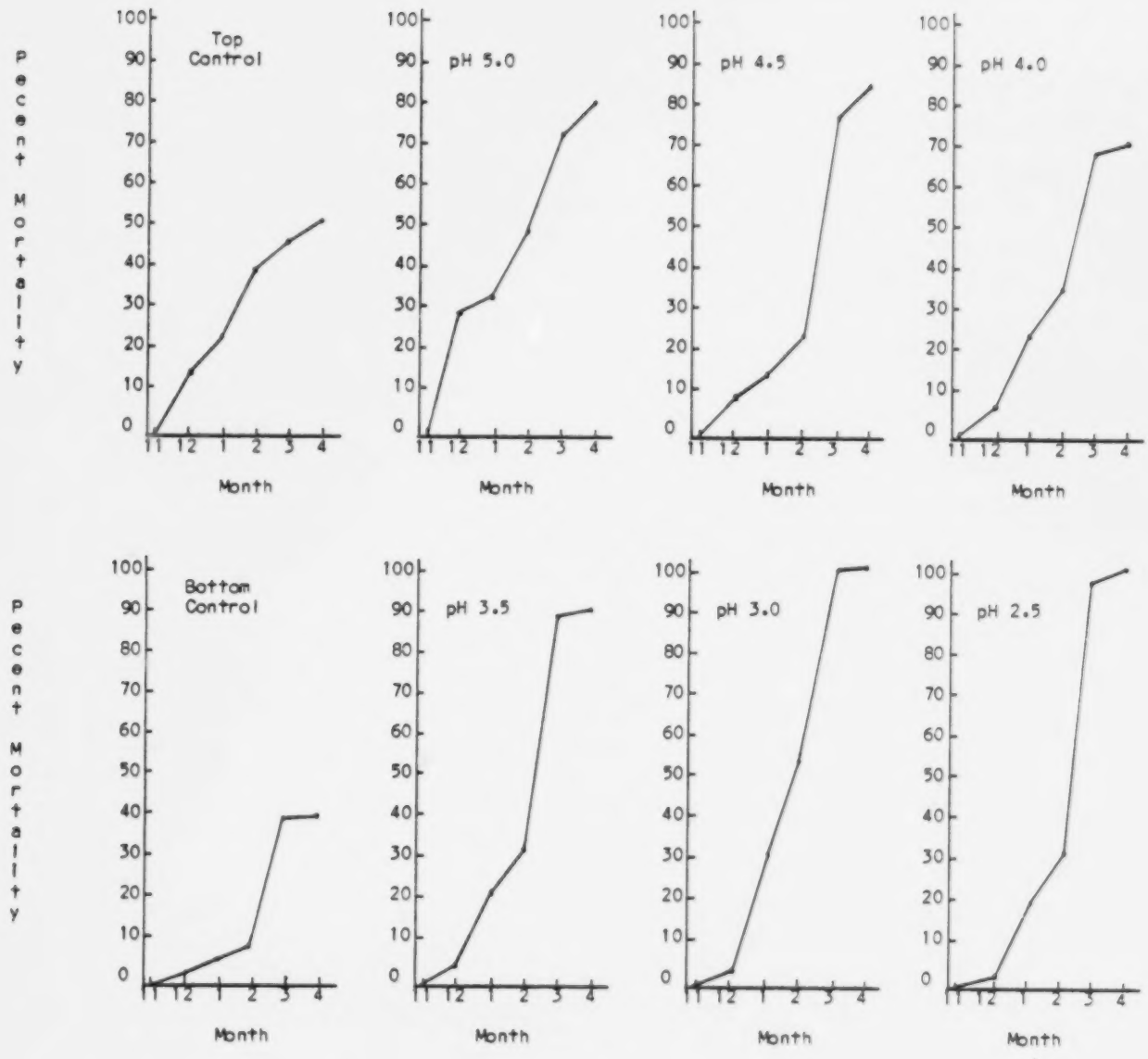

Figure 2. Mortality Curves for Control and Study Groups (% Mortality) (Beginning of each month of study).

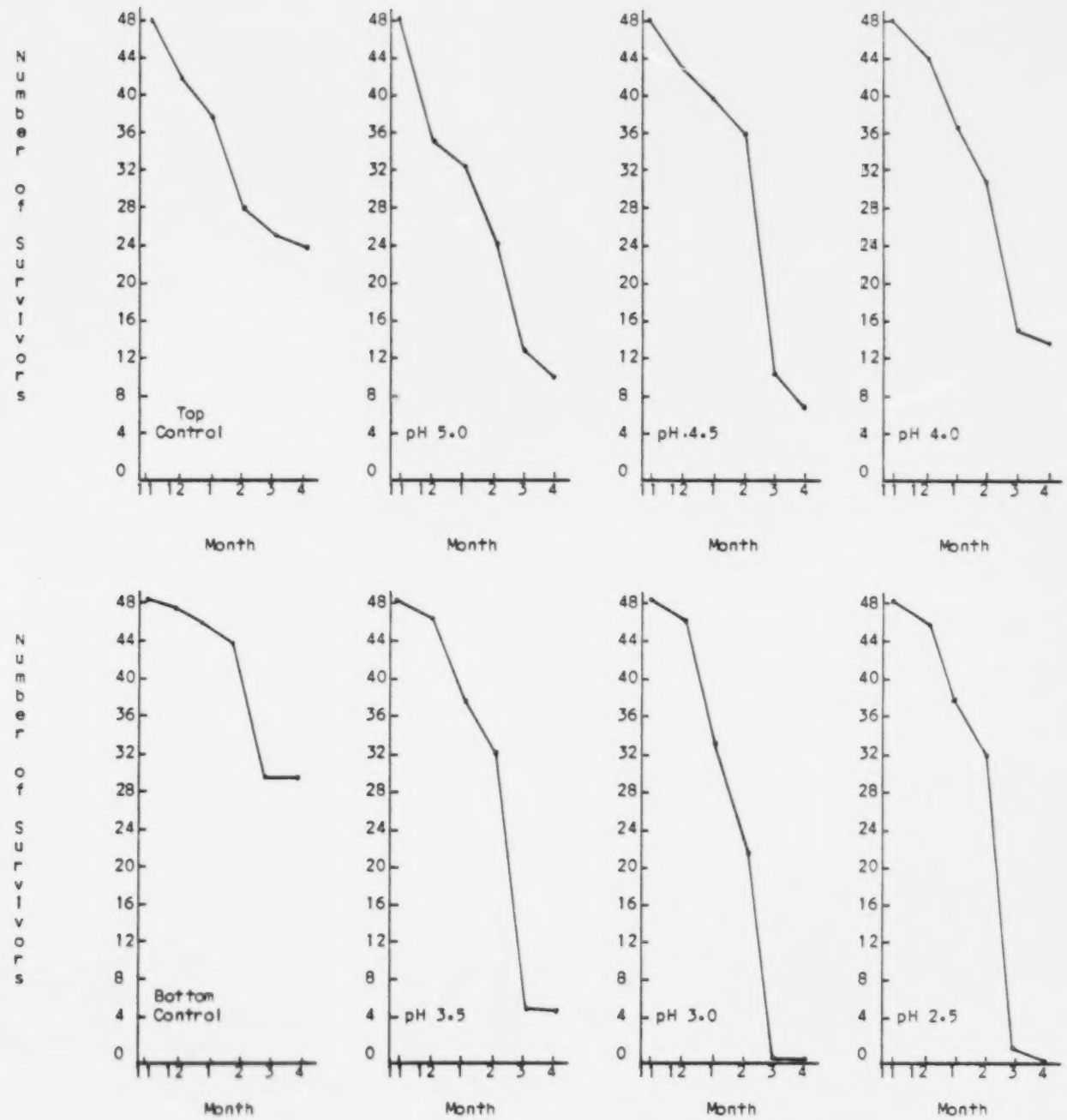

Figure 3. Survivorship Curves for Control and Study Groups (Number of survivors at beginning of each month).

Life Sciences

Effect of simulated acid rain on drosophila

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Overview

The effects of pH on the survival of fruitflies (*Drosophila*) in media of varying pH.

Objectives

AFTER THIS ACTIVITY STUDENTS SHOULD BE ABLE TO:

- know ways to investigate and measure properties of living things.
- know conditions which promote changes in living things.
- examine evidence critically.
- choose the most appropriate means of expressing results or observations.
- describe effects of acid rain on an organism.
- voluntarily seek additional information about the issue.
- hypothesize relationships between organisms and changes in their environment.
- systematically observe, record analyze, and interpret data from an experiment.

Materials needed

EACH STUDENT/STUDENT TEAM WILL NEED:

Instant *Drosophila* medium
1, 15 mL beaker *or* other 15 mL container
6 Plastic shell vials
6 Polyfoam plugs to fit shell vials
Labels or masking tape
pH indicator paper
Anesthetic
Drosophila culture - wild type

OPTIONAL

6 *Drosophila* culture vials

Teacher guidelines

1. Introduce this lesson by placing two columns on the board: Environmental Change and Organism Response. Ask students for examples of animal responses to environmental changes they have read about or seen. Be sure students describe the environmental change and the response of the organism. Questions to help guide this discussion:

   - Can changes bring about more than one response? What are some examples?
   - Are there any examples listed of two (or more) changes that brought about the same response?
   - What is a favorable change you could make in the environment yielding a positive response by organisms?
   - Are there more vertebrate examples than invertebrate examples?
   - What are some ways organisms might respond when humans change the environment?
   - Are the ways humans change the environment generally positive or negative for other organisms?
   - What is an example of an environmental change that hurts other organisms? Protects other organisms?
   - What are some environmental changes which cause humans to respond? What was the response?
   - Are all environmental changes caused by other organisms good? Example?

2. As an out-of-class experience, have your students focus their attention on three organism-environment interactions. Ask students to report their observations in the next class period. Questions to help guide the discussion:

   - What are some of the environmental factors involved, e.g., season, day length, temperature, food, water, etc.?
   - Are any of the changes locational, e.g., migration of birds in the spring and fall, roosting, food-related, etc.?
   - Are any of the changes seasonally related?
   - Do any of the changes involve changes to another stage in the life cycle of an organism, e.g., a tadpole to a frog, an egg to a bird, etc.?
   - Are humans involved in any of these environmental changes? In what ways? Are the changes good or bad for the organisms? Can any of the changes involving humans be modified so that they are less harmful? How?

3. Divide the class into student teams/small groups, distribute the Drosophila Laboratory sheet and review the assignment. It should take the remainder of the class period to set up the experiment. Then it will take a few minutes at the start of each class for the next three weeks to collect and record data. During the last class period, students will summarize results, prepare their data for interpretation and start writing their reports.

4. Allow about twenty minutes in the next class period for students to complete reports. Summarize the lesson with a brief class discussion. Questions to help guide this discussion:

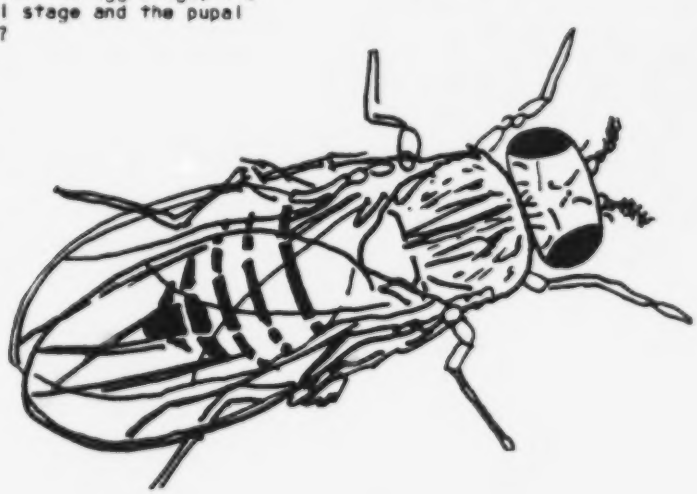
   - What are the variables in this experiment? What are the ones you investigated? What are the ones you controlled?
   - What is the variable on the x-axis of graphs you prepared? On the y-axis? Which would you call the responding variable? The manipulated variable?
   - Does this experiment tell you more about the tolerance of Drosophila to foods of varying pH or about the possible response of Drosophila to rain of varying acidity as well? What are some reasons?
   - Did any of the vials contain eggs? Larva? Pupa? Which ones? What do you infer?
   - What is an experiment we might do to learn more about the effects of simulated acid rain on adult Drosophila?
   - Suppose we wanted to examine the effects of simulated acid rain on the life cycle of Drosophila. How could you use the following equipment to find out if there is an effect due to pH on the egg stage, the larval stage and the pupal stage?

List the materials on the board: acidic solutions of varying pH (5), distilled water, Drosophila medium, Drosophila culture, petri plates or Drosophila culture vials, Drosophila females (fertilized), and spray bottles (for acidic solutions, distilled water).

Divide the class into groups of two or three and ask them to develop a research plan. Each group will have five petri plates (or Drosophila culture vials), a solution of an assigned pH, and distilled water. Encourage students to diagram and label their procedure. Since Drosophila has a 13-day life cycle, day 13 will end the experiment.

Note: Counting will become a problem in this experiment if it is carried out. It should not interfere with a discussion of a possible experimental design. If counting becomes important, ask about it. Students will then have to devise a way to count eggs, larvae and pupa. (If petri plates are used a grid would be drawn on the petri plate cover.)

You may find it useful to ask some of the following questions: In this experiment, what is the variable that is manipulated? The responding variable (What is being counted?)? What are the variables controlled by the investigator? Why might an investigator have two controls, a container, with Drosophila medium and eggs, to which no water is added and a container, with Drosophila medium and eggs, to which distilled water has been added? How are the acidic solutions added? Why aren't they added to Drosophila medium from the outset?



DROSOPHILA LABORATORY SHEET

MATERIALS:

Drosophila medium
15 mL beaker
6 plastic shell vials
6 polyfoam plugs to fit vials
Labels/Tape
Drosophila flies
Acidic solutions: pH 1, 2, 3, 4, 5, and 6

PROCEDURES:

1. Place 15 mL of dry Drosophila medium into each of the six vials.
2. To each vial, add 15 mL of a different acidic solution. Check the pH and designate the vial appropriately.
3. Anesthetize at least 150 flies from a healthy stock culture of wild flies.
4. Place 25 flies into each of the vials and leave the vials on their side until the flies become active. Then place the vials upright.
5. Each day count the number of flies in each vial, and record the data.
6. Make a table and a graph from your data that show the total number of survivors each day.

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When you have completed your work write a report which effectively communicates your results. Use this outline for your report:

I. Hypothesis Tested
II. Laboratory Procedures
III. Data
IV. Results (Interpretation)
V. A Question for Further Study

Exchange your report with another team. Rate each section of the reports according to the following point system and checklist. Before you exchange reports you may find it useful to rate your report based on these criteria. There may be sections you want to revise!

Point System:

0 = Poor
1 = Fair
2. = Satisfactory
3 = Good
4 = Very Good
5 = Excellent

Section Evaluation

Hypothesis -- Is it clearly stated? Does it indicate what will be manipulated or changed and what the response to that change might be?
Laboratory Procedures -- Are they clearly stated? Could another person repeat this experiment based on the description?
Data -- Are the data presented in a way that helps reveal probable relationships between variables? Are tables and graphs, including x- and y-axes, clearly and accurately labeled?
Results (Interpretation) -- Is the conclusion supported by the evidence, based on the data collected and information available?
A Question for Further Study -- Is the question interesting? Is it testable?

PRE-POST TEST

FRUIT FLIES

1. What effect might acid rain have on lakes in Northern Minnesota.

   A - None because those lakes can buffer or neutralize acid.
   B - The same effect as on lakes in Southern Minnesota.
   C - It could kill the Drosophila which would cause the trout to starve.
   D - It could reduce the amount of Lemna and possibly other aquatic plants.

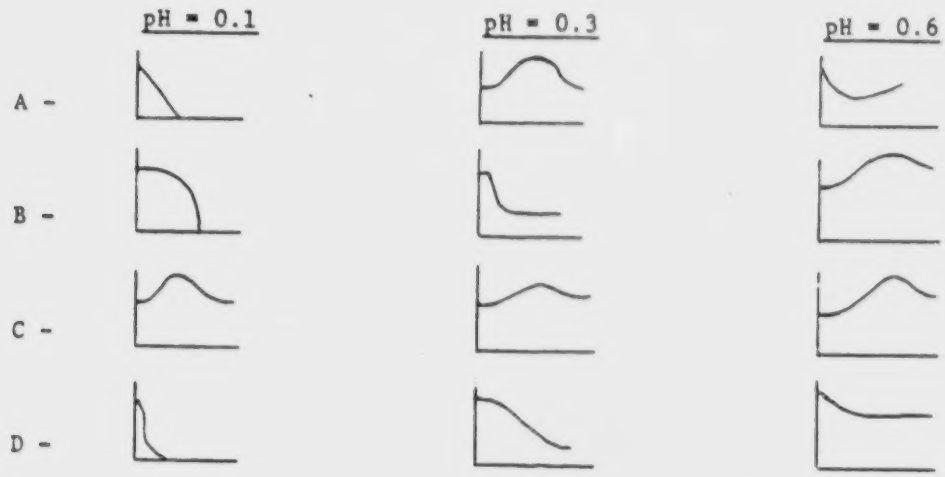
2. In the Drosophila experiment which vial acted as the control?

   A - The vial with pH 0.1 because it had the strongest acid.
   B - The vial with pH 0.3 because it's pH was in the middle.
   C - The vial with pH 0.6 because it was nearly neutral.
   D - This experiment had no control.

3. In dealing with Drosophila for this experiment it is important to keep in mind that:

   A - Drosophila are also used in genetic experiments.
   B - Drosophila are fruit flies and live off fruits - some of which (like citrus fruits) - are acidic.
   C - Some of the Drosophila may not be attracted to the medium under any circumstances.
   D - The experiments with Drosophila also apply to all other types of flies.

4. Which graph sentence below represents the population of Drosophila for pH 0.1, pH 0.3, and pH 0.6. The number of Drosophila is on the vertical axis. Time is on the horizontal axis.



5. Which of the following would be a valid hypothesis based on the results of the experiment with Drosophila?

   A - If an acid environment has an effect on Drosophila then it could have an effect on other organisms.
   B - If an acid food supply is harmful to Drosophila then acid rain may also be harmful.
   C - If the acid rain problem gets worse, then it could have an even greater effect on organisms.
   D - All of the hypotheses are valid.

6. Which measurement best represents a collection of data?

   A - The mean because it is the average of all data.
   B - The mode because it represents a relationship to the average.
   C - The mean, the mode, and the range should all be used to represent data.
   D - The range because it's the most comprehensive picture of all the data.

7. One advantage graphs have over tables is:

A - Graphs give a quick, visual image of the trends in data.
B - Graphs are much more accurate.
C - Graphs are faster and easier to do with less chance of error.
D - Graphs take up much less room than tables.

8. The experiments with acid rain demonstrated that:

A - Acid rain could help solve the problems of insect and weed pests.
B - Acid rain has little effect on plant and animal life.
C - Acid rain has the potential of damaging plant and animal life.
D - We need to develop species of plants and animals which are resistant to acid rain.

9. Perhaps the best solution to the acid rain problem is:

A - Since its effects are so slight it is not something to worry about.
B - Neutralizing acidic water areas.
C - A combination of pollution control equipment and energy conservation.
D - Developing acid resistant plants and animals.

1-D, 2-C, 3-B, 4-D, 5-D, 6-C, 7-A, 8-C, 9-C

Life Sciences

Effects of simulated acid rain on duckweed

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Overview

Investigate the effects of simulated lake basins of varying conditions of pH, on vegetative reproduction in duckweed (Lemna).

Objectives

TO DEVELOP STUDENTS ABILITY TO:

- o use instruments to describe qualitative and quantitative properties.
- o examine evidence critically.
- o choose the most appropriate means of expressing experimental data.
- o voluntarily seek additional information.
- o know conditions which promote changes in living things.
- o distinguish observations which are relevant to the solution of a problem from those which are not.
- o approach a problem scientifically.
- o describe effects of acid rain on an organism.
- o select the graphical form most appropriate to communicating the information.

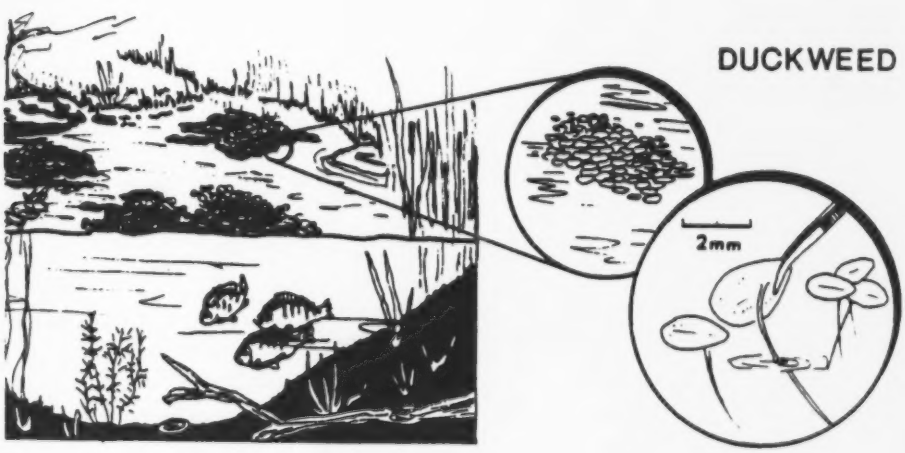
Materials needed

FOR EACH TEAM OF 4 YOU WILL NEED:

Duckweed plants (60)
Stereomicroscope
Tape or marking pencil
Small culture dishes - 6
Covers: petri dish lids/plastic wrap

DRAWING DUCKWEED

Vegetative reproduction occurs when a mature frond produces new fronds. One mature frond may give produce to two or three young fronds. As the young fronds mature and increase in number, the plant separates into individual plants. If conditions are favorable, a plant may reproduce within a day or two. Genetically, the young plant is the same as the parent plant.



Duckweed is a small aquatic flowering plant found on the surface of many fresh water ponds. The plant has leaflike structures called fronds and, usually, a single rootlet.

Teacher guidelines

1. Write the term ENVIRONMENTAL FACTORS on the board. Anything that affects the development, growth, survival and reproduction of organisms is an environmental factor. There are two kinds of environmental factors: biotic - those environmental factors which come from organisms, and abiotic - those which do not come from organisms and which are part of our physical and chemical environment.

   Ask students to list environmental factors for aquatic plants. Allow about five or ten minutes to discuss the factors they identify. Questions to help guide the discussion:

   - Are there more biotic or abiotic factors listed?
   - Is shade an environmental factor? Is it biotic or abiotic?
   - What effects might these factors have on aquatic plants?
   - What environmental factors listed are caused by humans? Are these factors generally good or bad for aquatic plants?
   - For environmental factors caused by humans, what kinds of effects might environmental factors caused by humans have on people?

2. Divide the class into groups of four, distribute the Duckweed Laboratory Sheet, and review the assignment. Take the remainder of the class period to set up the experiment. Take a few minutes at the start of each class for two weeks to collect and record data. During the last class period, students will summarize results, prepare graphs and answer the questions on the laboratory.

3. Conclude the lesson with a discussion of the results. Use these questions as a guide:

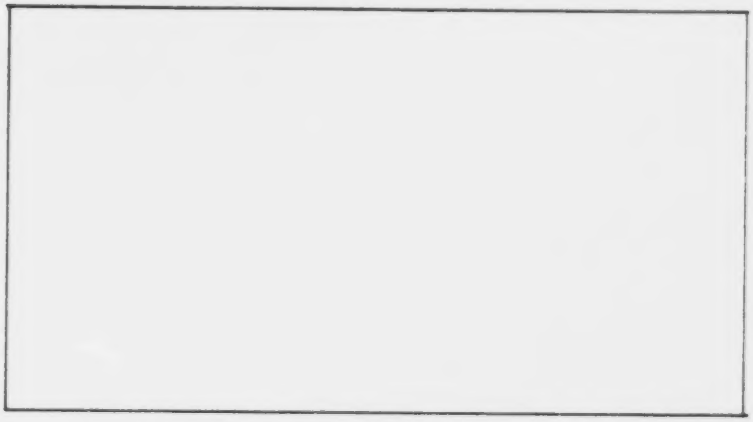
   - What are the environmental factors in this experiment? Which are biotic? Abiotic?
   - Is it possible to answer this question: What impact on aquatic ecosystems might an increase in the pH of rain have? Explain your answer.
   - Is there a reason to be concerned about acid rain? Why?
   - In order for an experiment to be a "fair" test, only one variable can be tested at one time. Every other part of the experiment must be the same. Why? Was this a fair experiment? Why or why not?

DUCKWEED LABORATORY SHEET

PROCEDURE:

1. Examine a duckweed plant under the stereomicroscope.

   a. Locate fronds and rootlets.
   b. Make a sketch of what you see.



   c. If you had to name this plant in a descriptive way, what would you name it?

2. Label six culture dishes and place 150 mL of one different pH solution in each dish.

3. Place 10 duckweed plants into each culture dish.

4. Cover each dish.

5. Place the covered dishes in a well lighted area.

6. Each day, for the next two weeks, count the total number of plants in each culture.

7. Record the observed numbers in a table.

8. Construct a graph on the back side of this sheet showing the data for each of the six dishes. Label the x- and y-axes.

ANSWER THESE QUESTIONS:

1. Does there appear to be any relationship between the pH of the "lake basins" and the reproduction of duckweed? Explain your answer.

2. a. What is the variable that was changed (manipulated) in a systematic way?
   b. What is the variable that measured corresponding changes -- the responding variable?
   c. What variables were held constant?

3. Which of the culture dishes served as a "control"? What was its purpose?

4. How would you determine the biomass of duckweed in each culture dish?

5. What experiment on duckweed might be done next to learn more about the effects of acid rain?

PRE-POST TEST

DUCKWEED

1. In the duckweed experiment which solution was used as a control?

   A - pH 0.1 because it's the base solution.
   B - pH 0.6 because it's near normal.
   C - pH 0.3 because it's in the middle.
   D - pH 0.7 because it is neither acidic or alkaline.

2. What is the purpose of using a control for the duckweed experiment?

   A - It is necessary to have a basis for comparison.
   B - Without a control the duckweed might grow too fast.
   C - A control is needed to see which acid solution has the greatest effect.
   D - Controls are part of every experiment.

3. Which acid solution showed the most harmful effect on the growth and reproduction of duckweed?

   A - pH 0.6
   B - pH 0.4
   C - pH 0.2
   D - None of these.

4. Some of the rainfall and snowfall has had a pH of 4.0. What effect might this have on duckweed in lakes?

   A - It could cause it to grow faster because of the fertilizing effect.
   B - It might inhibit it's growth and possibly eventually eliminate it.
   C - It could cause it to mutate during it's growth cycle.
   D - It probably would not have any long term effects.

5. The best way to determine the effect of acid on the growth of duckweed would be to:

   A - Find the biomass.
   B - Count the number of plants.
   C - Visual check for plant damage.
   D - all of these.

6. What effect might acid rain have on lakes in Northern Minnesota?

   A - None because those lakes can buffer or neutralize acid.
   B - The same effect as on lakes in Southern Minnesota.
   C - It could kill the Drosophila which would cause the trout to starve.
   D - It could reduce the amount of Lemna and possibly other aquatic plants.

7. If the duckweed population in an open water area were reduced what effect could it have on the food web?

   A - There could be fewer secondary consumers such as ducks and geese.
   B - There could be an increase in the numbers of other plants and animals because more light could penetrate the water.
   C - The entire food web could be reduced both in numbers and diversity.
   D - There would be an increase in decomposer species to deal with the dead duckweed.

8. Which measurement best represents a collection of data?

   A - The mean because it is the average of all data.
   B - The mode because it represents a relationship to the average.
   C - The mean, the mode, and the range should all be used to represent data.
   D - The range because it's the most comprehensive picture of all the data.

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B - Neutralizing acidic water areas.
C - A combination of pollution control equipment and energy conservation.
D - Developing acid resistant plants and animals.

1-B, 2-A, 3-D, 4-B, 5-A, 6-D, 7-C, 8-C, 9-A, 10-C, 11-C

Life Sciences

Learning from earthworms

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Overview

Are earthworms tolerant of acid soils or acid rain? In this activity students investigate some of the responses to one group of soil-living animals, earthworms, to simulated acid rain.

Objectives

AFTER COMPLETING THIS ACTIVITY STUDENTS SHOULD BE ABLE TO:

- willingly assume responsibility for the care of living things.
- distinguish observations which are relevant from those which are not.
- identify the essential steps in approaching a problem scientifically.

Materials needed

FOR THE CLASS

Shallow pans (dissecting trays, paper shirt/cardboard boxes lined with plastic, etc.)
Earth worms (Sow bugs and pill bugs may also be used.)
Paper toweling
Acid Solutions, pH 2-6
Medicine Droppers/Dropper Bottles
Laboratory Sheets, Wormturns 1 and Wormturns 2
Hand lenses (optional)

Sow bugs and pill bugs are much more light sensitive than earthworms. If students use them they will have to take this into consideration in the design of their experiments.

FOR THE SOLUTIONS

Rubber bulb pipettes/dropping bottles
Stirring rods
10% H_2SO_4
Cylinder(s) or Graduated beaker(s) - The size is not important but laboratory glassware with a capacity greater than 250 mL will expedite measuring 500 mL quantities of solutions.
Spring water
6 Stock bottles/containers - At least 1000 mL. Any clean container with a cap and which has a dripless spout.

HOUSING AND FOOD

Earthworms: Wooden containers are best (cigar box or greenhouse flat size). The soil should be damp, rich in humus or peat moss (2-6") and with a layer of leaves over the top. The box can be covered with cardboard. It should be kept in a temperature range of 45° to 65°F. A large variety of foods may be used: small amounts of cornmeal can be scattered over the top of the soil; twice a week bury small pieces of break soaked in milk and pieces of lettuce; etc. It is important not to add too much food at a time and to remove any that becomes moldy. If the soil is rich in humus, feeding is almost unnecessary. The environment should be kept damp.

Sowbugs and Pillbugs: A terrarium or bowl (8-10" diameter) containing damp, rich humus with small rocks or pieces of wood under which the organisms can hide. Cover with a piece of cardboard. Food: small pieces of potato, fruit, lettuce and even small earthworms. The environment should be kept damp.

Teacher guidelines

1. Organisms respond to environmental change; this is one of the basic characteristics of life. The repertoire of responses that characterizes an organism is called its behavior and the diversity of behaviors exhibited by organisms is quite simply remarkable. Introduce this lesson by asking students for examples of the ways organisms respond to environmental change. Allow about five or ten minutes to discuss the events they identify. Here are some questions which will help guide this discussion:

   - o What kinds of environmental changes were involved?
   - o How many organisms were affected by these events?
   - o What kinds of effects did/might the events have on the organisms?
   - o Are the most of the environmental changes listed natural or human-made? How did you decide?
   - o Have any of these events become problems? What is being done to resolve them?

2. It is not unusual for some students to be reluctant to handle earthworms. These students can assist others who have handled earthworms. Eventually, most of the reluctant handlers will join in.

   It is important that students become familiar with the behavior of the earthworm before they do the acid rain investigation. This acid rain activity relies on careful observations and the experimental design students choose will rely, to a great extent, on familiarity with the behavior of the earthworm.

   Give students a copy of WORMTURNS 1 and go over the instructions and assignment with them carefully. Because there is more than can be done in one laboratory period, assign or have students choose items from the list of possibilities.

   Emphasize the welfare of the organism: the earthworm is to be returned, unharmed, to the worm farm. There is a rule: earthworms should always be permitted to choose where they want to go during the work.

3. Next, explain that this lesson is designed to help students understand the potential impacts of problems related to acid deposition. Give students a copy of WORMTURNS 2 and go over the assignment with them carefully.

   You will probably have to give students some help in designing their investigation. Examples of pre-laboratory discussion questions follow:

   - o What do you think will happen if an earthworm is given some habitat choices of different pH? Will earthworms show a preference for a specific pH? Will they avoid them?
   - o What do you think will happen first: the earthworm will move toward preferred habitat or the earthworm will move toward any habitat?
   - o What is the regular behavior of an earthworm in a tray?
   - o How do you think you could get an earthworm to "tell" you something about habitat preference?
   - o What should you do to find out?
   - o What are some variables which may influence the behavior of the earthworm?
   - o What are the variables which you intend to manipulate (change) in a systematic way?
   - o What will you watch for, that is, what is the responding variable?
   - o What variables will you keep the same (hold constant) while you are changing one variable and observing the response of another? How can you be sure that the earthworms respond only to what is being tested?

Again, emphasize that earthworms are to be returned unharmed to the worm farm when the investigation is over. Remind them of the rule: earthworms should always be permitted to choose where they want to go during the work.

4. Ask these kinds of questions to guide a discussion of the results.

   - o What exactly can we say about earthworms and pH preferences? Is this the way it works in nature?
   - o What has been investigated? What hasn't been investigated?
   - o What are some of the major sources of variation in this experiment?
   - o How could we get more reliable or consistent results?
   - o Tally the results on the board. How much variability was there in outcomes? What are some of the reasons?
   - o What appears to be the most ideal pH? The least?
   - o In what ways could the experiment be improved; i.e., made more consistent or more reliable?
   - o What does the experiment tell you about possible relationships between acid precipitation and earthworm behavior? Earthworm survival?
   - o What additional experiments does this investigation suggest?

WORMTURNS 1

MATERIALS

Earthworms
Tray
Metric ruler
Hand Lens (Optional)
Watch with second hand (Optional)
Assortment of "papers": plastic sheets, plastic wrap, waxed paper, paper toweling, notebook paper, aluminum foil, etc.

A. Before you take your earthworm from the worm farm answer these questions:

1. I have/have never touched an earthworm (Circle one).
2. When I think of earthworms I _____
   _____
3. Three things earthworms need are _____
   _____
4. Earthworms are _____
5. I will treat the earthworm I study with respect. I fully intend to return it unharmed, when I am finished observing it, to the worm farm. The earthworm will always be permitted to go where it wants to go during the work.
   /S/ _____

B. Place an earthworm in a tray and answer these questions:

a. What does your earthworm look like? Draw a sketch and label it (You can use biological names or names that you invent which are descriptive.). Is there a front end? How do you know? How does the front end differ from the rear end?

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b. How long is the earthworm?

c. If available, use a hand lens to answer these questions about your earthworm.

- o Does it have eyes?
- o A mouth?
- o Blood vessels?
- o Is it smooth?
- o Legs?

d. See whether you can find the heart and locate it on your drawing. Can you see any evidence of a heartbeat? Is it fast or slow?

- o What does the earthworm do if you lift the tray at an angle? (Place a book under one end of the tray.)

e. Watch your earthworm and record your observations, e.g.,

- o How does it move?
- o Can it move backwards as well as forward?
- o How fast does it move?
- o What does it do when it meets an obstacle? (Place a pencil in its path.)

f. Carefully place your earthworm on three different surface materials, e.g., on plastic, dry paper, wet paper, smooth paper, rough paper, a wet tray surface, plastic wrap, aluminum foil, etc. Observe the worm for one minute on each surface.

- o Which surface is best for crawling? Is there any surface the worm can't crawl on?
- o Is there any evidence of choice, i.e., in general, do worms prefer dry or wet surfaces? What is the evidence you are using?
- o If you know where an earthworm is at a particular time can you predict where it will be 30 seconds later? A minute later?
- o Does your earthworm respond positively or negatively to light? How sure are you? Why?

C. In this laboratory

I learned that I _____

_____

I learned that earthworms _____

_____

I would like to know this about earthworms: _____

_____

_____

WORMTURNS 2

What would happen if you placed an earthworm in a container in such a way that it was presented with a choice of moist paper toweling, each of a different acidity, to crawl over or to crawl to? Experiments have been described as one way that humans have of asking questions of nature. The assignment is to conduct an experiment that will provide meaningful results.

MATERIALS

Earthworms
Pan or box lined with plastic
Acidic solutions: pH 2 - pH 6
Paper toweling
Medicine Droppers or Dropper Bottles

Question:

Will earthworms show a preference for habitat (think of the acid paper as habitat) of a specific pH?

Definition:

You have to find a way to measure the variable called habitat preference. (You can't ask the worms directly; this is the reason for the experiment.) In the space below write what you mean by habitat preference.

_____

_____

_____

Measurement: What?

The variable, habitat measurement, must be defined in a way so that it can be measured. It must, if possible, be quantified. If habitat preference cannot be quantified you must develop a description of how to recognize it. What will you measure to help you decide whether the earthworm has a preference for habitat of a specific pH?

Some possibilities might be: the worm will avoid the moist paper of a certain pH; the worm will crawl on a moist paper of a certain pH and stay there; the worm will crawl on a moist paper of a certain pH and stay there for _____ second(s); when presented with moist papers of different pH the earthworms show a preference.

Make a decision on the measurement you will use and write it in the space below. Write at least one argument against your decision and decide how serious it is to your experiment.

Measurement: _____

_____

Argument Against Decision: _____

_____

_____

The argument is a serious/not serious (circle one) objection because: _____

_____

_____

Measurement: How?

How and when will you measure the habitat preference of earthworms? Will you place worms in the center of a pan surrounded by a pattern of pH papers (Should the worm be placed initially on the pan surface, on a dry piece of paper, on a thin layer of soil, on...?)?; should worms be placed in the center of a pan with the pH papers crumpled and scattered in the "corners" of the pan?; should worms be presented with one trial pH at a time?; will you use one worm at a time or several worms at a time?; or should worms...?

On a separate sheet of paper make a diagram of your experiment.

Measurement: When?

When will you take your measurements? Within 10 minutes after placing the worm in the test situation or 40 minutes after or after 24 hours (and how will you keep worms from drying out if you do this?)?

_____

_____

Will you perform the trail once or more than once and why? _____

_____

This is when I plan to measure the variable of earthworm habitat preference: _____

_____

_____

_____

Table

Design a chart for recording your observations. The chart and the columns should be labeled.

INTERPRETATION

Do earthworms show a pH preference? _____

What is the evidence?

_____

_____

How good is the evidence? (Include your reasons.)

_____

_____

What I know as a result of doing this experiment:

_____

_____

Questions for further study:

_____

_____

"WORMTURNS"

1. Castings are:

   A - worm food
   B - worm waste
   C - worm homes
   D - worm trails

2. Worm burrows do not:

   A - improve drainage
   B - use up top soil
   C - aerate the soil
   D - help root penetration

3. The best temperature range for earthworms is:

   A - 10° - 25° F
   B - 45° - 65° F
   C - 75° - 100° F
   D - 0° - 50° F

4. The environment where worms are kept:

   A - should be sandy
   B - should be in sunlight
   C - should be airtight
   D - should be damp

5. Earthworms like to eat:

   A - bread and lettuce
   B - raw meat
   C - once a week
   D - insects

6. If you heard of an area which had 5,000 worms per acre,

   A - you would know that it was very acid soil
   B - you would know that it was very alkaline soil
   C - you would know that it was neutral soil
   D - you would know that number was unusually high
   E - none of these

7. When handling live earthworms:

   A - you should keep them moist
   B - you don't need to be careful because they don't have any feelings
   C - you should wear rubber gloves
   D - you must be careful so they don't bite you

8. Which of the following does an earthworm have?

   A - a nose
   B - eyes
   C - a mouth
   D - legs
   E - ears

9. An earthworm:

   A - has no circulatory system
   B - has no blood vessels, but blood in its body
   C - has blood vessels but no heart
   D - has blood vessels and heart

For each of the following stimuli, answer whether a worm would respond:

A - positively
B - negatively

10. light

11. moisture

12. acid

13. dry surface

14. an obstacle

15. fall

Assume you have found that a worm will avoid paper of a certain pH. For each of the following statements answer:

A - it is a valid conclusion
B - it is definitely false
C - not enough evidence for this conclusion

16. Worms will die when exposed to this pH.

17. Worms will not reproduce when exposed to this pH.

18. Worms will go deep underground when exposed to this pH.

19. Worms will not be affected when exposed to this pH.

20. Worms will avoid paper moistened with water at this pH.

1-B, 2-B, 3-B, 4-D, 5-A, 6-E, 7-A, 8-C, 9-D, 10-A, 11-A, 12-B, 13-B, 14-B, 15-B, 16-C, 17-C, 18-C, 19-C, 20-A

Life Sciences

Effects of acid rain: Hay infusions

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Overview

In this activity students investigate the effects of solutions of varying acidity on microscopic life in pond water. Students should be able to prepare wet mounts. Although not absolutely necessary, students should also be familiar with the kinds of protozoa commonly found in pond water and hay infusions. The names of the protozoa are not nearly as important as being able to differentiate protozoa by shape, size, methods of locomotion and other observational clues.

Objectives

AFTER THIS ACTIVITY STUDENTS SHOULD BE ABLE TO:

- describe the consequences of different pH levels on microscopic life in pond water.
- keep appropriate records in order to observe change in systems.
- predict the effect of certain changes through observation of similar changes.
- appreciate the need for measurement and know when approximate methods may be more useful than careful measurement and vice versa.
- develop methods for solving observational problems.
- use scientific instruments to extend the range of human senses.
- know ways to investigate and measure properties of living things.
- demonstrate to others the effects of acid rain on ponds in a laboratory simulation.

Materials needed

Depending on class size you may want to set up several observation and distribution stations to facilitate observation, access to, and distribution of materials. The materials and methods will have to be modified accordingly. If you do so, hay infusion amounts could be reduced from 1000 mL to 500 mL/station.

5-7 glass or plastic jars, 1000 mL
Plastic wrap
Rubber bands or masking tape
10% H_2SO_4
Glass stirring rods, 2
Medicine droppers, 2
Graduated cylinder, 250 mL - 1000 mL
pH paper, narrow range, pH 2 - pH 8 or pH meter
Water, 5000 - 7000 mL, spring, tap, or pond, not softened or distilled
15-20 grams of hay
Microscope slides
Cover slips
Hand lenses
Microscopes
Lens paper
Cheesecloth/pantyhose/cardboard

OPTIONAL:

Material for quieting and slowing the movement of protozoa - methyl cellulose, polyvinyl alcohol, gauze, thread, lens paper
Microscope slides, depression
pH meter

HAY INFUSIONS - MATERIALS

1. Collect dry grasses, weeds, leaves or hay from areas that are flooded by sheet run-off from snow in the spring -- almost any depression will do as long as it has not received its water from highways which may be rich in salts and other pollutants. You will need 2-3 grams for each infusion (Use the same amount for each).

2. Collect wet grasses, weeds, leaves or hay from recently flooded areas. You will need 4-5 grams for each infusion (Use the same amount for each). If you do this, be sure to measure the pH of any standing water from the sample area.

3. Commercially prepared timothy hay.

HAY INFUSIONS - PROCEDURES

1. Carefully wash, rinse and dry the jars, stirring rods, graduate cylinders and medicine droppers.

2. Boil 5.5 - 7.5 liters of spring, tap or pond water for 10 minutes. (A covered glass pot is suggested although enamelware can be used.)

3. Pour 1000 mL of water into each jar.

4. Cover the jars with plastic wrap immediately and seal the jars with rubber bands or masking tape. Cool to room temperature overnight.

5. Add 10% sulfuric acid to the first jar according to the recipe provided.

6. When you are finished, you will have 5-7 jars with a pH that ranges from 2 to 8, depending on your source of water.

7. Once you are sure the pH is stable, add about 1.5-2 grams of hay to each of the jars. Be sure to add the same amount to each jar.

8. Cover the jars loosely with cheesecloth/pantyhose/pieces of cardboard to allow air to enter and to reduce evaporation. You can use plastic wrap to minimize evaporation if you punch a few air holes in it.

9. Store the jars in an area where conditions are reasonably constant. An abundant growth of protozoa usually will be available in one to two weeks. The culture can be checked periodically to ensure an adequate supply. The infusions may develop an unpleasant odor, but this does not harm the microscopic life.

ADVANCE PREPARATION

The jars of acidified water should be prepared a day in advance of this investigation. The measured quantities of hay can be added either before the investigation or the day work is introduced to students. The laboratory work should be arranged so that you start this investigation on either a Monday or a Friday.

Teacher guidelines

1. Show students the jars and describe how they have been prepared. If premeasured quantities of hay have not been added to the jars, add them now. Tell students that some animals will soon begin to grow in these habitats and that it will take from one to two weeks for this to happen. Divide the class into teams and give each team a copy of the Hay Infusion Observation Sheet. Tell students you want them to keep records of what they see during the period before they begin more detailed microscopic examination of these habitats. The period of hay observation by naked eye may have to be extended before microscopic examination becomes worthwhile. If rooms are between 70° to 80° the containers are likely to be teeming with life within a week.

Give students a few minutes each day or every other day to make their observations.

As students make their observations during the next five to ten days, hold informal class discussions and ask for reports of student observations. You might ask questions such as:

- What are the environmental factors you can see?

- How would you describe this system? What are its component parts?
- What are some of the initial values, e.g., color, odor, pH, water clarity, arrangement of the parts, etc.? Can any of these variables be quantified?
- What are the properties of the system?
- Given the component parts of this system, what are some changes you can look for?
- What are the initial conditions?
- What color is the water? The hay?
- Is the condition of the hay the same as it was?
- Is the condition of the hay in each container the same? Is there any relationship between the condition of the hay and the pH of the container? If so, what is it?
- What happens to the habitats as they grow older?
- Are there differences between the top, middle and bottom of these habitats? If so, how would you describe them?
- What is the first change you saw?
- What new changes have occurred?
- Are the changes uniformly distributed through the habitat?
- Which system changed the most? What is your evidence?
- Can the jars be rank-ordered in any way other than the pH labels? If so, how? What criteria are you using? Are the criteria ones which are easy to describe and on which you can get general agreement? Should they be? Why or why not?
- What is a way that observations in these systems could be recorded to provide clear evidence of changes in the systems? (A chart could be developed describing the system at the beginning, at a later time, and at a still later time.)
- Is there any evidence from these systems you can use to help you decide that microscopic examination of these habitats might be worthwhile? What is it?

2. If students are not familiar with some of the common protozoa found in pond water/hay infusions, give them an opportunity to become familiar with these microorganisms. Use the container with the richest profusion of life and have students make wet mounts and examine them under the microscope. As students work, ask them these kinds of questions and use these kinds of statements:

   - Is there anything in the water?
   - What do you see?
   - Are all of the life forms you see the same or are there different life forms? How many different kinds?
   - Does it make a difference where you took your sample from the container in the kinds/numbers of microorganisms? Top, bottom or middle?
   - How would you slow organisms down if you wanted to study them more carefully? Suggest some ways to slow them down and have students try them.
   - What do you think some of these organisms use to move with?
   - Do all organisms move the same way? How many different kinds of ways do the micro-animals seem to move?
   - Draw a circle to represent your microscope field. Sketch the shape of the most common kind of animal you see. Use a few words to describe its behavior.
   - Draw a circle to represent your microscope field. Sketch the shape of the least common kind of animal. Use a few words to describe its behavior.
   - Draw a circle to represent your microscope field. Sketch the shape of the largest kind of animal you see. Use a few words to describe its behavior.
   - Draw a circle to represent your microscope field. Sketch the shape of the smallest kind of animal you see. Use a few words to describe its behavior.
   - How can you tell the difference bewteen an air bubble and an organism?
   - Make a sketch of all the different microorganism shapes you see. How many are there? Have you got them all?
   - Do any of the organisms show any color(s)? What color(s)?
   - How would you describe the color(s) of most of the microorganisms you see?
   - Do the microorganisms move in one direction only or do they move both forward or backward?
   - Do any of the microorganisms appear sensitive to light? Have you tried adjusting the amount of light? How do the microorganisms respond to this?

3. When the class is ready to examine the cultures with a microscope, write two questions on the board: "What is the optimum pH for artificial pond microorganisms?" and "What is the range of pH for the artificial pond microorganisms?" The experimental design for this investigation has already been chosen by the manner in which the infusions were initially set up. This part of the investigation focuses on constructing operational definitions for variables.

HAY INFUSION OBSERVATION SHEET

Team Members: _____

_____

Date hay infusion started: _____

Record what happens to the hay infusions.

Day 1.

_____

_____

_____

_____

Day 2.

_____

_____

_____

_____

Day 3.

_____

_____

_____

_____

Day 4.

_____

_____

_____

_____

Day 5.

_____

_____

_____

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OPTIMUM AND RANGE pH SHEET

Team Members: _____

Date: _____ _____

(1) How can you find the range of pH for artificial pond microorganisms?

(2) What is the optimum pH for artificial pond microorganisms?

For each of these, draw and/or describe how you will quantify -- measure -- these variables.

What do you think is the range for artificial pond microorganisms? _____

What do you think is the optimum pH for artificial pond microorganisms? _____

This is the stage during an experiment during which the investigator not only identifies relevant variables but also devises ways for measuring the variables that can be quantified.

List the materials available to students on the board unless you want them to discuss what equipment they can use for this investigation: microscopes, microscope slides -- plain and depression, cover slips, "slowing" equipment, and medicine droppers.

4. Divide the class into research teams, distribute copies of the Optimum pH Sheet and have the teams decide on a way/ways that they can use their hands and selected equipment to answer the two questions asked. Ask students to draw and/or describe their procedures and then try them. Encourage procedural modifications which provide better results. When students have made their measurements, have them answer the questions at the bottom of the sheet. When the investigations are completed, the equipment should be cleaned up and returned.

5. Let each team decide its experimental techniques and report the data collected. Place a number line on the board to be used as a class record of the data. Have students suggest a name for the chart and a label for the number line. As students make their reports, ask them these kinds of questions:

   - How well do you trust the experimental design you used?
   - What are the variables in the technique you devised?
   - What did you keep constant?
   - How many tests did you use? Do you think this was enough? What can you offer in support of your claim?
   - How did you take samples from the container? Do you think you should have taken more?
   - If you were to repeat this experiment what would you change, if anything? What is at least one reason?
   - What assumptions did you make?
   - What was the most difficult part of this investigation?
   - What is the major advantage and disadvantage of the technique you used?

Also elicit from them how the data should be recorded. As each team makes its report have them record the data.

After students have completed their reports, the class should try to reach some conclusions based on the following questions:

- In how many different ways did the class attempt to answer these two questions?
- Did all groups recognize the same measurement variable? What were some of the reasons?
- Did any of the ways include measurements of time? Organism size? Organism shape? Kinds of organisms? Number of organisms? How were they used?
- Which data were most convincing? Explain. Which data were least convincing? Explain.
- How many tests are necessary to produce reliable data?
- Place a number line on the board to be used as a class record of the data.
- In this experiment, was there an experimental control? What was it? What was its purpose? What variable(s) in the control were held constant during the course of the work?
- Is there any acidic solution in which no microorganisms were found? How good is the evidence?
- What do you know as a result of this investigation? What is the evidence?
- Should we perform another investigation two days from now? A week from now? What are your reasons for deciding that it is either worth or not worth the effort?
- What observations did you make? What inference(s) can you make about species preferences from the data?
- Do these pond microorganisms show a clear and convincing optimum range? What data can you cite to support your answer?
- At what pH, if any, do major changes begin to occur?
- Do all microorganisms have about the same range of tolerance to changes in pH? Which life forms appear to have been most affected? Least affected?

- How would you define these terms: Range or Environmental Range and Optimum or Environmental Optimum? (These concepts can be defined in several ways. Student responses for range should include ideas of maximum and minimum, an environmental factor, and values or intensity of the environmental factor under consideration. Student responses for optimum should include ideas concerning the part of a range in which an organism survives best for a particular environmental factor.)
- What would happen if you were to repeat this investigation?
- In this experiment, how safe are we in assuming that pH accounted for the differences?
- If a different acid were used as a precipitation source (for example nitric acid instead of sulfuric acid), what do you think would happen?
- What are some ways this experiment could be modified to improve it?

Resources

William A. Andrews (Editor). 1972. A Guide to the Study of Freshwater Ecology. Prentice-Hall, Inc., Englewood Cliffs, NJ.

Biological Sciences Curriculum Study. 1975. Biological Science: Invitations to Discovery. "Who's Who In the Pond Water World", pp. 67-70; "Microscopic Organisms", pp. 249-260. Holt, Rinehart and Winston, Inc., New York.

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PRE-POST TEST
HAY IN(pH)USIONS

This test assumes the student has completed parts one and two of this activity unit.

1. The most obvious effect of acid precipitation on lakes has been:

   A - loss of fish populations.
   B - increase in bacteria populations.
   C - loss of protozoa populations.
   D - increase in algae populations.

2. Which statement is correct?

   A - invertebrates never eat decomposers.
   B - invertebrates eat only decomposers.
   C - invertebrates get some energy by eating decomposers.
   D - invertebrates get all their energy by eating leaves.

3. A hay infusion is made from:

   A - dry hay only.
   B - wet hay only.
   C - wet or dry hay.
   D - wet or dry grasses and weeds.
   E - dry grasses from near a highway.

4. In making hay infusions:

   A - it doesn't matter how much water you use.
   B - you should use the same amount of water for each one.
   C - you should be sure to vary the amount of water used.
   D - you should always use 10 ml. of water.

5. Hay infusions:

   A - should be kept tightly covered with plastic wrap.
   B - should never be covered at all.
   C - should be covered with fabric that lets air in.
   D - should be left uncovered 15 minutes each day.

6. On an agar plate culture:

   A - molds are shiny.
   B - molds are fuzzy.
   C - bacteria are fuzzy.
   D - bacteria are always green.
   E - molds are always green.

7. While the hay infusion jars are being stored:

   A - each should have a different light and temperature.
   B - each should have the same light and different temperatures.
   C - each should have the same temperature, but different lighting.
   D - each should have the same light and temperature.

8. If you observe bubbles in a jar:

   A - you can conclude that microorganisms are present.
   B - you can conclude that the water is boiling.
   C - you can conclude that some gas is being released.
   D - you can conclude the experiment is a failure.

9. The best temperature at which to store the hay infusions is:

A - between 20°-30° F.
B - at exactly 98.6° F.
C - between 70°-80° F.
D - at 0° F.
E - between 100°-120° F.

10. If the water in the jar is very clear you can assume:

A - that few if any organisms are present.
B - that the water is very clean and good for drinking.
C - that many organisms are present.
D - that the water has a low acid content.

11. The organisms that appear in the jars:

A - were living in the water and multiply when hay is added as a food source.
B - were living in a dormant form in the dry hay.
C - were present in neither the hay or the water, but were created when the two were mixed.

12. Agar is:

A - a type of acid.
B - a type of bacteria.
C - a type of food for bacteria.
D - a type of mold.

13. The petri plate to which no water is added is called:

A - the variable.
B - the hypothesis
C - the placebo.
D - the control.

14. If any bacteria or mold had grown in the agar-only petri plate:

A - it was present in the agar.
B - it may have been from the air.
C - it was probably on the dish.
D - none of these. It is not possible.

15. From your experiment, it seems as though the most microorganisms grow on petri plates:

A - to which highly acidic water was added.
B - to which no water was added.
C - to which less acidic water was added.

Life Sciences

Responses of radish crops to simulated acid rain

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Overview

The effects of simulated acid rain on succeeding crops of radishes, under varying pH conditions are investigated.

Objectives

After completing this activity students will be able to:

- describe some effects of acid precipitation on plants and on succeeding crops of plants.
- use scientific equipment to extend the range of human senses.
- choose the most appropriate means of expressing observations.
- represent data to discover relationships.
- describe changes in the physical and biological environment brought about by human activity.

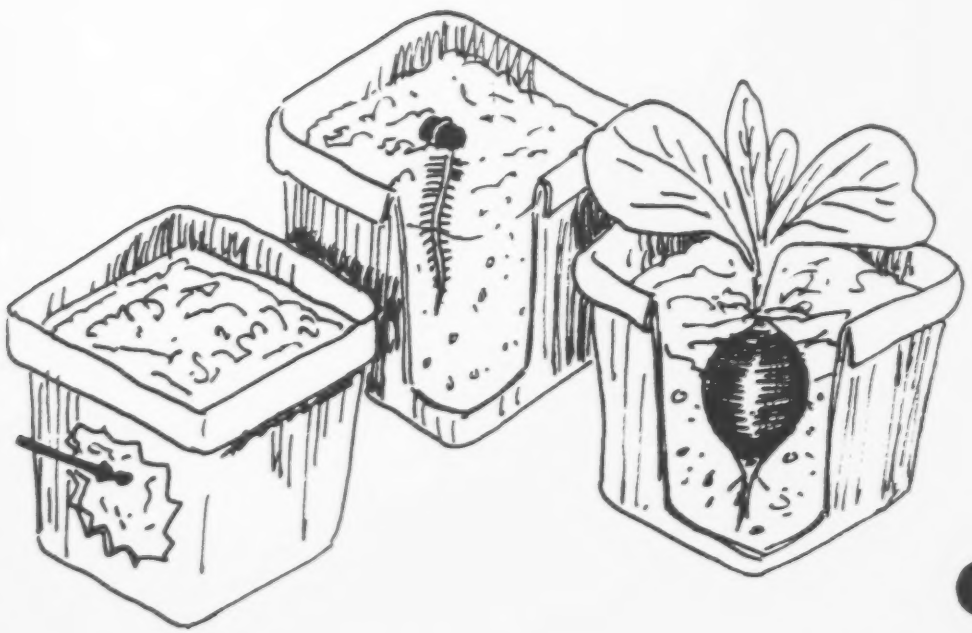
Materials needed

FOR THE CLASS

Radish seeds
Potting soil
30-40, 2"-3" plastic or clay plant pots or peat pots or school lunchroom milk cartons
pH paper: narrow range, 2-7
Masking tape
Distilled water
Beakers
Beam balance
Incubator (optional)

FOR THE SOLUTIONS

Rubber bulb pipettes/dropping bottles
Stirring rods
10% H_2SO_4
Cylinder(s) or Graduated beaker(s) - The size is not important but laboratory glassware with a capacity greater than 250 mL will expedite measuring 500 mL quantities of solutions.
Spring water
6 Stock bottles/containers - At least 1000 mL. Any clean container with a cap and which has a dripless spout.



Teacher guidelines

1. Students probably know that lakes and forests are at the center of the controversy over the effects of acid rain. They may not know that there is also some potential for crop damage where acid rain is severe. Research conducted at Argonne National Laboratory (Illinois), which is operated by the University of Chicago for the U.S. Department of Energy, has shown that, even within legal limits, acidic pollution can reduce soybean yields.

   Explain to students that this lesson marks a shift in their study of acid rain. This lesson focuses on the effects of artificial acid rain on a sequence of plant and harvest rotations.

2. Use the following questions as the basis for a pre-laboratory discussion. Accompany your questions and discussion with diagrams.

   - What do you think will happen if you grow radish seeds in several containers and add a different acid solution -- an artificial rain -- to each container?
   - What do you think would happen if, as soon as the second leaves appear, you harvested the entire plant, planted another radish seed, and followed the same acid watering procedure?
   - What do you think would happen if you repeated this again? -- harvest the plant as soon as the second leaves appear, planted another radish seed, and followed the same acid watering procedure.
   - What should you do to find out?

3. Divide the class into small groups of about five students, give each group a copy of the Radish Instruction Sheet. Go over the instructions with them carefully. Students will need some help. Circulate from group to group; listen, answer, and ask questions.

   This activity uses three planting trials. Emphasize the need for careful data collection and similarity of technique from trial to trial.

   A. In Trial 1, six radish seeds are planted. Each seed is watered with a different pH solution (2, 3, 4, 5, and 6); one of them is treated with distilled water. Each plant should receive the same amount of water. The soil should be kept evenly moist; not soggy. If you want, have students plant two seeds per pot. If both emerge, one can be removed.

   B. When the second leaves appear, students are to "harvest" the entire plant. Show students how to remove the plant (roots and shoots) from the container. They should carefully shake the soil from the roots of the plant and replace this soil in the appropriate pot. The harvested plant should be placed on paper toweling, labeled, and dried.

      If you have an incubator, use it. However, classrooms are notoriously dry and the plants will air dry quickly. When the plant is dry, shake any remaining soil from the roots (Hold the roots and tap them with a finger.) and weigh the plant to the nearest 0.01 of a gram. Record all data.

   C. Trial 2. Immediately plant another radish seed in the same soil and follow the same procedure as in Trial 1.

   D. Trial 3. Repeat.

   E. Students may need some help in graphing their data, especially in deciding what goes on what axis. The manipulated or input variables, the pH solutions, are recorded on the x-axis. The responding or outcome variables, the gram dry weight (GDW), are recorded on the y-axis.

4. After each group has completed its research, the class should try to reach some conclusions based on the following questions. You may want to make an overhead of the pooled class data and place them on an overhead so that all your students can see them.

   - In what ways are the curves alike? Different?
   - What variables do you think influenced the growth of the plant?
   - Place three columns on the board under the following headings: Trial 1, Trial 2, Trial 3. Then call upon students to list the variables in each trial. Which variables changed the least from trial to trial? The most? What are your reasons?

- Often in research one variable is manipulated, another responds, and the remaining variables are held constant. Ask students to identify the manipulated variable, responding variable and variables held constant in trial one. In our experiment, was more than one variable manipulated during the trials? Was this by design or because it could not be helped?
- What variables should have been held constant during this experiment?
- What other values could have been assigned to measure the responding variable, radish plant growth?
- What was the purpose of using distilled water in this experiment?
- Place six columns on the board under the following headings: pH 2, pH 3, pH 4, pH 5, pH 6, Dw (Distilled Water).

Ask each group for the data collected for each pH for one of the trials. What is the range? How would you describe the variability in the data to someone? What are some of the sources of variation? Are the data from each group "acceptable" to you? What reasons do you have for saying that? What are some reasons for combining the data into a single number and using it to make a composite class graph?

- How could you find out which variable influenced the differences (if any)?
- If you were going to repeat this experiment, how would you improve it?

RADISH INSTRUCTION SHEET

TEAM MEMBERS: _____

_____

1. Collect the following equipment: Radish seeds (6), potting soil, and plant pots (6). Note: there are three trials in this experiment and you will use thirty radish seeds for the entire experiment.

2. In addition to the equipment you collected, there are five different pH solutions and distilled water in stock bottles. There are also triple beam balances available for your use. During the experiment you will also need items such as masking tape, paper toweling, etc. Your teacher will tell you where they are in the laboratory.

   How can you use the equipment listed, the solutions, and the balance to learn about the effects of acid rain on the growth of radish plants through three plant and grow cycles? You will look for evidence of effects of artificial acid rain by weighing the plant. Be sure to include this procedure in your plans.

   Each plant will be a source of data. Include a table which shows how you are going to keep track of each plant and what data you are going to collect.

   When you have a plan, check it with your teacher. If it is OK, s/he will give you permission to proceed. Teacher's signature: _____

3. If you cannot think of a way to test the hypotheses discussed before the laboratory, set up the experiment according to your teacher's diagram.

4. Graph your data. Label the x-axis, the y-axis, and give your graph a title which describes what the graph is about. What can you say about the effects of simulated acid rain on a plant and grow harvest cycle?

5. Collect the data recorded by the other research groups and make a class graph. Be sure to include your group's data! Label the x-axis, the y-axis, and give your graph a title which describes what the graph is about.

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Life Sciences

Rainwater/Snowmelt: A limit to growth

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Overview

This is a process skill experimenting activity. It helps students understand the nature of science as an ongoing and tentative search. Students will act as scientists: actively observing, hypothesizing, experimenting, collecting and organizing data, and drawing conclusions.

Objectives

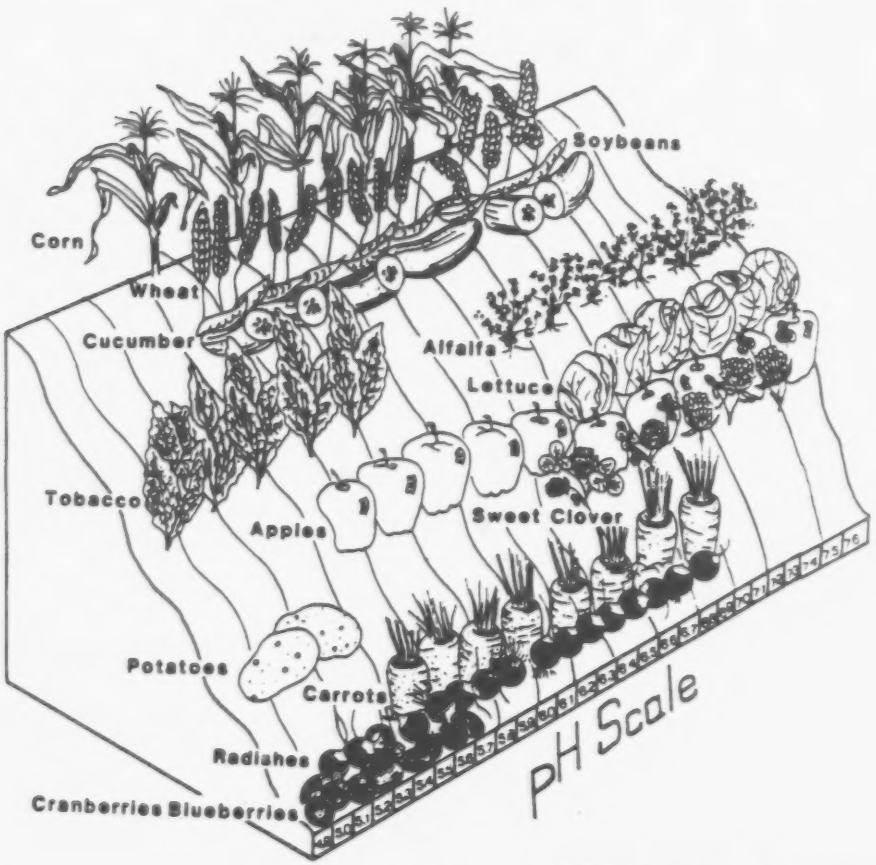
AFTER COMPLETING THIS ACTIVITY STUDENTS SHOULD BE ABLE TO:

- ask testable questions.
- identify variables which might affect a hypothesis.
- choose an appropriate experimental design to test a hypothesis.
- collect, record, organize, interpret, and report quantitative data.
- make generalizations - most likely explanations - from data.

Materials needed

- Whole plants/cuttings: Coleus, Begonia, African violet
- Vermiculite
- Small jars/plastic cups/plant pots
- pH paper
- Variety of vegetable seeds
- Paper towels
- Blotter
- Sponge
- Hand lens
- Plastic wrap
- Trays/Cardboard boxes (shirt, shoe)
- Research Report Form

Note: The materials will vary depending on the experiment.



BEST COPY AVAILABLE

Teacher guidelines

1. A major goal of this lesson is to help students better understand how to convert a problem about acid rain into an experiment. This is a teacher led discussion on the class construction of a fair experiment. You begin with a problem or a question -- preferably one of your own choosing -- and ask students to participate in the solution.

2. The first step is asking an appropriate question. Many such questions can be asked about acid rain.

   - How does rainwater/snowmelt affect the germination rate of seeds?
   - What would happen to plants if you fed them rainwater/snowmelt?
   - How does rainwater/snowmelt effect cuttings from plants?
   - What effect will pre-soaking seeds in rainwater/snowmelt have on their germination rates?
   - How does rainwater/snowmelt affect a rooting leaf cutting?

3. Choose a question and discuss the experiment with your students. The procedures include:

HYPOTHESES

A hypothesis is a tentative explanation. The reason for using a hypothesis is to help determine which of all of the available data may be used as evidence.

You may prefer hypotheses which are stated in an if...then form. These kinds of hypotheses begin with an if statement and end with a statement beginning with then:

If the concentration of the acid is increased, then the reaction rate will increase.

If there are differences in brands of paper towels, then the brand absorbing water faster will tear more easily than the other brand.

If two leaf cuttings are treated the same way except for the kind of water, then the one treated with rainwater will not grow and the other one will.

The then part of the statement represents an implication. It is the evidence that will either prove or invalidate the hypothesis. Students should be able to develop several different hypotheses to test. From this list, pick one to investigate.

Hypotheses can also be stated less formally. Students can state their best guess as to what will happen:

- Yes, cold water will freeze faster than hot water.
- No, cold water will not freeze faster than hot water.
- Plant cuttings are more sensitive to rainwater/snowmelt than they are to distilled water.

The form of the hypothesis is left up to you.

VARIABLES

These are the factors that change or can change in an experiment... amounts, temperature, lengths, instruments used, the investigator... Have students brainstorm a list of variables which might affect the hypothesis and list these on the board. There are two types of variables. A third, variable(s) held constant, is discussed below.

Independent or input or manipulated variable (e.g., type of water, distilled or rain/snow). The factor that changes or can be changed and is believed to affect the dependent variable.

Dependent or outcome or responding variable (e.g., growth). The factor believed to be affected by a change in the independent variable. The value of a dependent variable is known until after the experiment is conducted.

In the accumulation of evidence from experiments, investigators try to do three things. Change (manipulative) one variable. Look for and measure changes in another (the outcome) variable. Keep all the other variables the same (constant) while changing one variable and observing the response of another. This is difficult and central to scientific research. Ask students:

In the plan for this investigation, what is the independent (input or manipulated) variable? What reasons do you have for saying that? What alternatives are there?

What is the dependent (outcome or responding) variable? What reasons do you have for saying that? What alternatives are there?

what variables from the list on the board would you hold constant? How would you hold them constant?

Once the variables are identified, the task is to construct operational (measurement) definitions for both variables so that they can be measured. Another reason for doing this is that when the experiment is repeated by the same person or another investigator, it can be performed in the same way.

Again, have student brainstorm measurements and list these on the board. How do you measure growth? What do you mean by growth operationally? To continue the example, one operational definition for growth might be length of root system. Another might be number of roots. Be sure to ask how the controlled variables are going to be held constant.

DESIGN

Once the design is chosen, the data collection can begin.

How large a sample? To put it another way, if you just put one leaf cutting in rain/snow water and one leaf cutting in distilled water, how do you know whether any differences in growth rates came from the differences in water?

When to collect data.

When to stop the experiment.

What specific data should be recorded.

DATA ORGANIZATION

This step includes both tables and graphs. You might want to recommend appropriate tables and graphs or have the class help organize them.

Because each plant is used in the experiment is a source of data, there must be a way to keep them separate. An observation table must contain some starting, ending, and difference information.

Class data can be further organized by using a class chart and/or, when appropriate, histograms. A histogram is a graph showing how many of the trials, in this case plants, show a variable value, in this case growth. Graphs are very useful in revealing hidden relationships. As students work with graphs, help them understand the x and y dimensions: the x-axis (horizontal) is the factor changed (the independent variable); the y-axis (vertical) is the factor which changes (the dependent variable) in response to changes to the x-axis values. A graph shows how manipulating one variable effects another variable. Have students provide an appropriate title for the graph.

DATA INTERPRETATION

Does the experiment support or disprove the hypothesis? Can the experiment be interpreted better/differently in terms of other hypotheses? How sure are you of your decision? How do the data support your decision? Do other students agree with the interpretation? What conclusions can be drawn?

4. You may want to use this lesson to help students develop another skill: reporting the results of an experiment. Reports can take a great variety of forms. You may prefer your own. If not, give each student a copy of the Research Report form. Briefly review it to ensure that students understand what is expected of them. Students should attach the data on which the answer is based. Tables should be properly labeled. On a graph, each axis should be named with one of the factors and the graph should have a title.

5. Debrief the laboratory. Access to science is greatly encouraged when conversation with students occurs between you and them as co-learners in the experiment(s). The atmosphere that you create in discussing results must not be judgmental. The purpose in discussing results is to integrate ideas as well as to promote student reasoning. Use some of the following questions as well as your own.

- How much variability is there in the data?
- How valid are the data? How do you know?
- Would you say we have sufficient data?
- How many measurements should be made to report accurate data?
- Do we have evidence of a cause-and-effect relationship between two (or more) factors? What is the evidence? How good is it?
- What are some variables that might have affected the outcomes of the experiment?
- What are the important factors in this experiment?
- What assumptions have we made in this experiment? How safe are we in making them?
- If you were going to repeat this experiment, what would you do to obtain better data?
- What other experiments does this investigation suggest?
- What are some different ways we might test our original hypothesis?
- What do you believe as a result of doing this experiment? What reasons do you have for saying that? Suppose someone wanted to contradict your point of view. What evidence could they take?
- What are the possible interpretations of our work?

6. More Research Possibilities

- Does it make a difference if the rain is collected at the beginning or at the end of a storm?
- Does it make a difference if the rain is collected during a violent storm (thunderstorm) or from a gentle rain?
- Does it make a difference if the rain is collected in the open (rain gauge) or from your roof (downspout or a can under the eaves)?
- Does it make any difference if the snow is collected from the top or bottom?
- Is there a difference between fresh snow and old snow?
- Is there a difference between icicle water and snow water?
- Does it make a difference where the storm came from? (Hint: Use the day-to-day weather maps in your newspaper or watch the TV weather news to trace the path of a storm. Did it pass over any large cities or vast expanses of farmland or...?)
- Does it make a difference if the rain is collected at night or during the day; during the week or from a weekend rain?

PRE-POST TEST
pH: A LIMIT TO GROWTH

SCIENTIFIC EXPERIMENT

1. What is a hypothesis?

   A - An educated guess.
   B - A statement of procedures.
   C - A tentative explanation.
   D - An explanation of results.

2. Which of the following statements is a valid hypotheses for the "pH: A Limit to Growth" experiment?

   A - Acid rain reduces the growth of plants.
   B - If acidic rain water is used on plants then their growth will be adversely affected.
   C - Comparing rain water with the water should tell us something about plant growth.
   D - If acid rain affects the growth of African violets, then other plant growth will be affected.

3. What is a variable?

   A - Things that change or can change.
   B - Data which is graphed on x or y coordinates.
   C - Things that must be controlled.
   D - Independent and dependent variables.

4. Which of these variables must an experimenter be aware in doing this experiment?

   A - Temperature.
   B - Amount of light.
   C - The water quality.
   D - All of these.

5. Which of these results could you measure in this experiment?

   A - Presence of roots.
   B - Growth of new leaves.
   C - Weight gain of plants.
   D - All of these.

6. In this experiment why do you use tap water and rain water?

   A - You want to make a comparison of growth with the two types of water.
   B - Tap water must be used to prevent the plant from drying out and dying.
   C - Tap water is pure water and rain water has a lot of pollution.
   D - To demonstrate how plants grow after a good summer rain.

7. In designing your experiment it is important to think about:

   A - The pH of the tap water.
   B - The pH of the rain water.
   C - Chlorine in the tap water.
   D - All of these.

8. How can you be sure that acid is the limiting factor in this experiment?

   A - You can't, there are too many other things involved.
   B - You must control the experiment so that acidity is the only variable.
   C - By using only tap water, you make sure acid rainwater controls the experiment.
   D - By observing root growth you can see the effect of acid rain.

9. Which of these input variables should be controlled?

   A - The pH of the water.
   B - The water temperature.
   C - The amount and type of light.
   D - All of these.

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10. If the results of your experiment showed that acidic rainwater was harmful to the growth of coleus or begonia or African violet leaves, what would be a valid hypotheses for another experiment?

A - Acidic rainwater is harmful to plants.
B - Acidic rainwater only harms certain plants.
C - If acidic rainwater harms this plant, then it might harm others.
D - If African violets are harmed, then all African plants will be harmed.

11. One possible inference based on the evidence from this experiment is:

A - Emissions from power plants and automobiles is a major cause of acid rain.
B - Acid rain could cause plants to grow roots faster.
C - Acid rain could reduce the growth rate of plants.
D - Acid rain could damage the soil plants grow in.

12. Does it matter if the rain is collected at the beginning or at the end of a storm?

A - Yes, because rain has the effect of washing the air so the first part of the rain will have more pollution.
B - No, acid substances are in the rain when it falls, so all of it is equally polluted.
C - Yes, because lightning which changes air chemistry usually is most intense at the beginning of a rain storm.
D - No, the source of acid rain is somewhat constant from cars and industry, thus the air would be equally polluted.

13. Does it make any difference if the rain is collected during a violent storm (thunderstorm) or from a gentle rain?

A - Yes, because violent storms with lightning produce acid rain.
B - Yes, because thunderstorm rain travels through *more* air (thunderclouds are higher) than gentle rain clouds.
C - Maybe, but an answer cannot be given to fit all situations because there are too many variables.
D - No, the intensity of the rain has no effect on its acidity.

14. Does it make any difference if the rain is collected in the open (a rain gauge) or from your roof (a downspout) or can below the eaves?

A - No, rain is rain no matter where it falls.
B - Yes, by collecting it under a downspout, you can't be sure its quality wasn't changed after it fell.
C - Yes, by collecting it in the open you don't get enough in a rain gauge to use in an experiment.
D - No, normally a roof or gutter won't have any affect on the rains acidity.

15. Does it make any difference where the storm came from?

A - No, air pollution due to industry and automobiles is generally the same throughout the country.
B - Yes, if the storm came from a heavily industrialized area of the country it could contain more acid rain producing compounds.
C - No, all of our weather moves from the west to the east and the amount of acidity (pH value) is different for each storm.
D - Yes, most of our storms originate in Canada which has much more acid producing compounds than the U.S.

1-C, 2-B, 3-A, 4-D, 5-D, 6-A, 7-D, 8-B, 9-D, 10-C, 12-A, 13-C, 14-B, 15-B

RESEARCH
REPORT

Title:

Investigator(s): _____

_____

Date: _____

Class: _____

Problem Investigated

Procedure

Interpretations and Inferences

Life Sciences

Seed germination

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Overview

This activity will help students understand some of the potential for damage to plants from acid rain. Using simulated acid rain of varying pH, students investigate effects on seed germination.

Objectives

AFTER THE ACTIVITY STUDENTS SHOULD BE ABLE TO:

- identify the essential steps in approaching a problem scientifically.
- know ways to investigate and measure properties of living things.
- design experiments with effective controls.
- understand the nature and significance of changes in living things.
- choose the most appropriate means of expressing observations.
- examine evidence critically.
- develop methods for solving problems or testing ideas.
- distinguish observations which are relevant to the solution of a problem from those which are not.

Materials needed

Seeds, e.g., corn, wheat, bean, pea, melon, dandelion, locust, etc. Use locally grown seeds if possible.
Low pans: enameled/glass (or paper boxes lined with plastic wrap)
Rubber/Plastic gloves
Forceps ("Tweezers")
Beakers or suitable glassware: small, for pouring acid solutions
Plastic wrap/plastic sheet
Marking pencils/crayons
Scissors
Paper toweling

OPTIONAL MATERIALS

Petri plates
Plastic tumbler
Blotting paper

A NOTE ON SEED TESTERS

Distribute seeds on a paper towel, cover this towel with a second one, wet it with one of the acid solutions and roll toweling up (a "rag-doll" tester). Place the tester in a container (enamel pan/ glass pan/paper box lined with plastic) so that students have easy access to it. The tester should be kept moist. A sheet of plastic wrap over the top of the pan will greatly reduce evaporation. Label the pans and the toweling.

Petri dishes can also be used. Paper toweling should be cut to fit the plate and dampened with the appropriate solution. The seed "sandwich" will have two sheets on the bottom and two sheets covering the seeds.

ADVANCE PREPARATION

Germinate some seeds. The germination period depends on the seeds. Seeds from trees can take from a week to several months. Small seeds, for example, radish or mustard, usually germinate within 24 hours. Larger seeds such as beans, peas, corn, grains, and squash usually generate in 2 to 4 days. Germination can be hastened by soaking seeds overnight at room temperature.

The acidic solutions should also be ready when you introduce this lesson to the class.

Teacher guidelines

1. This activity explores concepts such as range, optimum, and limiting factors. As you introduce and discuss the work, relate it to these ideas.

   Remind students that many factors, for example, temperature, light, and water, affect plants during their life cycle. Additional environmental factors to which plants respond are chemicals.

   Show the students the seeds you germinated and describe what you did. Tell your students that many people have expressed their concern about the potential effects of acid rain, which consists of two major chemicals (SO_x, NO_x), on forests and agricultural crops. Now, show the students the acidic waters you made up and ask them how they could find out how _____ (name the seeds you used) respond to them. Allow about five or ten minutes to discuss the experiments and approaches they suggest. Here are some questions which will help guide this discussion:

   - o What reasons do you have for saying that?
   - o Does anyone agree (or disagree) on that point?
   - o What do you mean by the term you just used?
   - o How many seeds would you use?
   - o What are you assuming...?
   - o What is the question your experiment is trying to answer?
   - o What is your hypothesis?
   - o How will you measure germination? What will you measure?
   - o How do you decide when it is time to end the experiment?
   - o What are some of the variables which may influence the behavior of the system?
   - o What test would you use to determine the effects of one variable on another variable, the responding variable?
   - o In order for an experiment to be a "fair" test, only one thing can be tested at a time. All the other parts of the experiment have to be the same. What are some considerations that will make this a fair test?

2. Unless you use rainwater, there are six solutions of different pH to use in the work (2, 3, 4, 5, 6, and distilled water, approximately pH 7). Divide the class into small work groups.

   Give each student a copy of the Learning From Seeds worksheet, and review it with them carefully. Note any modifications to the materials needed list.

   Circulate from group to group, helping students respond to the questions and asking clarifying questions of them. You may find some of the questions asked above useful. As you work with groups, encourage students to talk to one another, e.g., "Kia, do you agree with Jim? Why or why not?" Ask, too, for clarification when necessary, "Can you tell me more? I don't understand what you mean."

3. Students may have questions about just what is a hypothesis. There are many ways to think about hypothesis. Hypotheses also take a variety of forms. For the purposes of this lesson, a hypothesis is a tentative explanation invented or devised by the investigator. Such explanations can be tested by an experiment. Data are gathered which either support or do not support the hypothesis. When the data do not support a hypothesis, the hypothesis must either be rejected or modified.

   Many questions can be asked about germination rates of seeds. How does temperature affect the germination rate of dandelion seeds? Does the age of seeds affect their germination rates? Will freezing of seeds affect their germination rates? As these questions are chosen for investigation, hypotheses are formed, for example:

   > Temperatures greater than 25°C will have an adverse effect on germination rates.
   >
   > If seeds of different age are treated the same way, then the younger ones will have a higher germination rate than the older ones.
   >
   > Frozen seeds from wild plants germinate better than frozen seeds from domesticated plants.

   Students have considerable observational information available to them about possible effects of varying pH. Many of them have watered home plants and worked in gardens. They may develop a hypothesis on the basis of these observations. One of many hypotheses students might formulate is: seeds treated with water of pH closest to that of tap water will grow best.

4. Students may need some extra help with variables. You may want to interrupt the group work for a class discussion of manipulated variables, responding variables, and variables held constant. You might pose a problem: Suppose two seeds are placed in containers of potting soil. They both receive

the same care except for watering. one is kept moist; the other is kept completely covered with water.

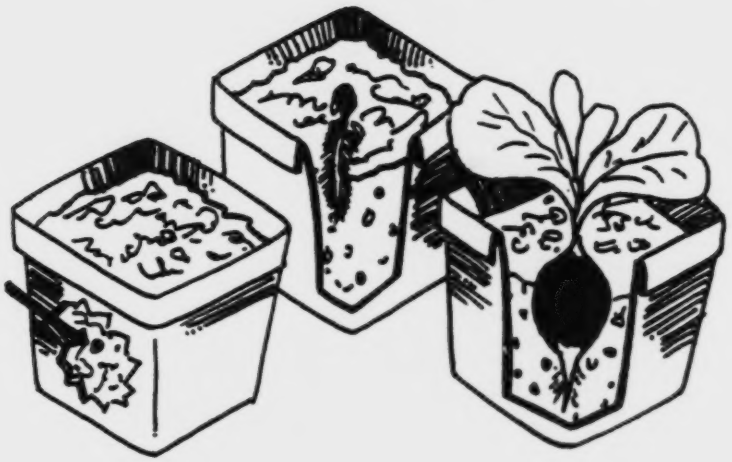
Have the class brainstorm a list of variable factors in this experiment. Once the list is on the board ask which are the variables held constant (VHC), the variable that is changed (manipulated) in a systematic way (M), and the responding variables (R), which are used to measure the change. Label the variables with the symbols. Use VHC rather than C for the variables held constant. The latter suggests constant variables and should not be used.

There are several possible responding variables in the student investigation. Students could measure seed growth (length), record germination rates (proportion %), emergence of the radicle from the seed coat (time), etc. Any of these may be used.

5. You should be prepared to help groups/the class with ways to test the hypothesis. A diagram and a short discussion should be enough, if students can think of no other ways to test the hypothesis.

6. Once the groups are organized and the investigation is under way, it will take only a few minutes during class for students to check the experiment (The papers must be kept moist.), make observations, and record their data. It should take a class period for each group to summarize results and to prepare their class presentations.

7. After student groups make their class presentations, use these questions to stimulate discussion and to help them turn their attention to the meaning of the work:



- Did all the groups agree on their findings? What were some of the differences, if any? How might they be explained?
- What do you infer from this study? What is the evidence you are using?
- What is the hypothesis we tested? What were the observations that support this hypothesis?
- From this experiment, what can you say about the potential impact of increased rain acidity on local crops? What would convince you to be concerned? What additional information would you like?
- If you used local rain water in your investigation, ask what was the pH of the rain water we used? How could you check this? What are some things you would like to know about the rain water? Do you think it makes any difference how the rain water was collected? Or where? Or when? Or how long it was stored? What experiments could we do to learn about ways to collect and store real acid rain?
- What other experiments could we do with simulated acid rain?
- How tolerant to differences in pH are these seeds? Is there a range? Is it wide or narrow?
- Does there appear to be an optimum pH? What are the data which support your answer?
- Is pH a limiting factor on the germination of these seeds? What is your evidence?
- Are there any other possible interpretations? What are your reasons?
- Did all the groups use the same responding variables? Which responding variables were most persuasive? Explain. Which responding variables were least persuasive? Or, didn't it make any difference?
- What other variable or variables might be tested in order to determine the effects of water of varying acidity on seed germination? State operational definitions for each.
- How would you characterize our results? Relatively reliable or relatively unreliable? What are some of your reasons? Does anyone else have a different viewpoint?
- In this experiment, how safe are we in assuming that the pH of the water accounted for the differences?
- What difference would it make if you used different seeds?

LEARNING FROM SEEDS

Research Group Members _____

You must become a member of a plant acid rain research group. The director of your laboratory has asked you to investigate a question.

Does the pH (relative acidity) of water solutions affect the germination rate of seeds?

How could you use the materials provided to find out if several water solutions ranging in pH make a difference in seed germination?

MATERIALS AVAILABLE

Seeds
Water solutions ranging in pH
Paper toweling
Low pans/Petri plates
Marking pencils/crayons
Plastic wrap
Transparent plastic rulers

DRAWING OF EXPERIMENT

- What seed will you use?
- What is the hypothesis you are testing?
- Complete the chart on the next page.
- What specific data will be recorded?
- How will the data be recorded? Prepare a suitable data collection table.

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Complete the following chart.

THREE VARIABLES	VARIABLES IDENTIFIED FOR EXPERIMENT
Manipulated (The one you change)	
Responding (The one you watch for change measure)	
Held Constant (The ones you keep the same)	

When you are finished, record the data on a graph. Label the horizontal and vertical axis. Give your graph a descriptive title.

Select a person who will describe the procedure used to obtain the data. Person: _____

Description: _____

_____

_____

Select a person who will clearly state the results - interpretations - of your work. Person: _____

_____ Results: _____

_____

Select a person (or persons) who will present all of the reasons - the supporting evidence - for your interpretation of the data. Person: _____ Experiments: _____

_____

Select a person to describe ways in which the experiment could be improved if it were to be repeated.

Person: _____ Improvements: _____

_____

LIMITING (pH)ACTORS:
pH AND SEED GERMINATION

1. The seed leaf which often contains stored food is called the:

   A - integument
   B - embryo
   C - cotyledon
   D - radicle

2. The outer layer of cells which develop into the seed coat is the:

   A - integument
   B - embryo
   C - cotyledon
   D - plumule

3. The first vegetative shoot of the embryo is the:

   A - integument
   B - cotyledon
   C - radicle
   D - plumule
   E - hypocotyl

4. The beginning of the new organism found in the seed is the:

   A - integument
   B - embryo
   C - radicle
   D - cotyledon
   E - hypocotyl

5. The tip of the embryonic root is the:

   A - integument
   B - cotyledon
   C - hypocotyl
   D - radicle
   E - plumule

6. The stem of the embryonic plants is called the:

   A - integument
   B - cotyledon
   C - radicle
   D - plumule
   E - hypocotyl

7. The process of sprouting of an embryo from a seed is known as:

   A - vaccination
   B - maturation
   C - germination
   D - variation
   E - conjunction

8. When mixing acid solutions to obtain a certain pH, you should:

   A - always take the pH measurement before stirring
   B - never stir the solution
   C - always stir the solution before measuring pH.
   D - always estimate the number of drops needed to obtain a certain pH.

9. A "rag-doll" tester:

   A - is used to test seed germination
   B - is used to test pH of test solutions
   C - is used to test the pH of rainfall
   D - is used to test the results of acid precipitation on adult plants.

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10. A guess at an answer of an untested theory is called:

A - a verdict
B - a conclusion
C - a hypothesis
D - a variable
E - a control

11. A factor that could influence the outcome of the experiment is called:

A - an hypothesis
B - a control
C - a conclusion
D - a variable

12. "Pure" rain has a pH of:

A - 5.0-6.0
B - 5.6-7.0
C - 6.5-7.0
D - 4.5-4.6
E - 7.0

13. Rainwater reacts with normal levels of atmospheric:

A - nitrogen oxide
B - sulfur dioxide
C - carbon dioxide
D - carbon monoxide

14. Which of the following would NOT be a good ending to this hypothesis? "If the vitality of a plant is negatively influenced by acid rain during the time that its seeds are germinating:

A - then plant deformations may result
B - then chances of survival may be increased
C - seeds may be delayed
D - fruits may be smaller
E - growth may be slower

15. One type of seed which <u>might</u> benefit from the effects of acid rain is:

A - bean
B - radish
C - corn
D - locust

16. Seeds will germinate:

A - only when planted
B - when exposed to moisture and proper temperatures
C - only in a petri dish
D - when wrapped in a dry paper towel

17. Which of the following should be kept constant when studying the effect of pH?

A - pH
B - temperature
C - light intensity
D - band c
E - none of these

18. Germination is <u>usually</u> considered complete when:

A - the seedling has become an independent plant
B - the seed coat has fallen off
C - the radicle has emerged
D - the plumule has elongated

1-C, 2-A, 3-D, 4-B, 5-D, 6-E, 7-C, 8-C, 9-A, 10-C, 11-D, 12-B, 13-C, 14-B, 15-D, 16-B, 17-D, 18-A

Earth Sciences

Ground e(pH)ects

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Overview

Students investigate the effects of acid solutions/simulated acid rain on soil parent materials, under varying pH conditions. This laboratory activity demonstrates some of the relationships between the mineral raw materials from which soil is formed, strong acid solutions, and artificial acid rain.

Objectives

After completing this activity, students should be able to:

- describe the effects of acids on soil parent materials.
- describe the relationship between concentration of acid solutions and their effect.
- demonstrate some effects of acid rain on soil parent material in a laboratory simulation.

Materials

Each student/team will need:

200 mL of an acid solution, pH range 2-3
pH indicator paper
2 burets/plastic columns
Rock samples, crushed limestone and crushed granite
1 ring stand
2 clamps, buret or round jaw
Plastic tubing
2 drain tube clamps
Masking tape/glass marking pencils
1 graduated cylinder - 100 mL
1 jug (Clean; large enough to hold 200 mL of acid solution, with a no-drip spout)
2 beakers
Safety goggles
Hammer
Towel/cloth
Meter stick

Optional:

Magnifier
Rock samples
Soil samples
Litter samples: leaf, needle, grass/hay
Artifical acid rain solutions, pH 4 and pH 5

Teacher Background

1. This activity was first used in a self-paced, earth science laboratory in which students selected the activities they wished to investigate. More than 20 students did this activity, but only one or two worked on it at a time.

   The original columns were recycled Earth Science Curriculum Project columns. After cutting, they measured 40 cm. long and 3.5 cm. diameter. These columns were already fitted with plastic nipples and wire screens (to prevent the drain from clogging). The tubes were filled with crushed rock to a level of 30 cm.

   Almost any plastic column material will work, although fitting the drain tubes and clamps may require some work and ingenuity. The final modified assembly that you and your students produce may also require some modifications in the solution amounts and times indicated. Standard buret columns can also be used. If you develop a successful modification, please share this with The Acid Rain Foundation.

2. Review laboratory safety procedures and rules for disposal of solutions with your students. It is strongly recommended, and is required in some states, that you and students wear eye protection during experiments involving acids. When the soil parent material is crushed, wrap the materials in heavy cloth and wear eye protection.

3. The activity can be extended by trying other materials in the columns, e.g., leaf litter, humus, grass/hay clippings, parent materials, as well as soil samples from wooded areas, lawns, fields, and agricultural crop areas.

Teacher Guidelines

1. Introduce this lesson by asking students what they recall and have heard about changes in materials associated with acids. Take about five or ten minutes to discuss the events they identify. Here are some questions to help guide the discussion.

   - What are some ways acids affect materials?
   - What would you look for as evidence of changes caused by an acid? Color? Odor? Any others?
   - Are changes in materials from acids reversible or irreversible?
   - How common are acids in everyday life? What are some examples?
   - What kinds of materials are liable to be attacked by acids?

2. Tell students that an "acid" of near world-wide concern is "acid rain." Acid deposition is often referred to as "acid rain" and occurs when sulfur and nitrogen oxides emitted by coal-fired power plants, smelters, vehicles, and other sources, both human-made and natural, are transported in the atmosphere and return to earth as acid compounds. (The term "acid deposition" refers to the depositing of these acid compounds from the atmosphere to the earth in both wet and dry forms.)

   Investigation of the effects of acid deposition has concentrated on lakes and fish, forests and agriculture, materials, and human health. Acid deposition's current aquatic damages are well documented, but thus far geographically limited. Areas in the northeast United States and southeast Canada have already suffered significant losses of fish populations from acid deposition. This has resulted from certain characteristics of the watershed, e.g., watershed size and shape, type of vegetation, bedrock, and soils and the length of time precipitation remains in the soil.

   In this investigation, we will examine one of these factors: bedrock type. Give students a copy of "Ground E(pH)ects Instruction Sheet" and go over the instructions with them carefully.

3. When the students have completed the work, use the questions on the worksheet as a basis for discussion. If you want and it is appropriate, discuss the idea of buffering -- the neutralization of acid as it filters through a lake's watershed.

Name: _____

Class: _____

GROUND E(pH)ECTS INSTRUCTION SHEET

1. Read the directions and make a list of the equipment.

2. Note any modifications in the procedures.

3. Set up the apparatus as shown in the diagram or as modified by your teacher.

4. For each column, clamp the drain tubes securely.

5. Fill each column to a level of 30 cm. (or to the level indicated by your teacher) with a different material -- limestone and granite. (The limestone and the granite must be crushed.)

6. Examine samples of each material and record any observations.

7. For each column:
   * Pour 100 mL of the acid solution into the graduated cylinder
   * Measure and record its pH value
   * Pour this acid solution into the column

8. After you have added the acid solutions to the columns, wait 10 minutes.

9. Record any observations (bubbles, noises, discoloration, etc.) for each column.

10. Drain the acid solutions from each column into separate collection beakers.

11. Measure and record the pH value.

12. Examine samples of each material and record any observations.

13. When you are finished, dispose of the solutions according to your teacher's instructions, rinse the rocks, clean the glassware and return all materials used in the investigation to the equipment desk.

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Answer the following questions:

1. What effect does the acid have on the materials? What is your evidence?

2. You have made several pH measurements and comparisons. Write a brief summary of your findings.

3. What is your interpretation of this investigation?

4. Based on your observations, which lakes would most likely be first affected by acid rain: those where the lake basins are mostly granite, or mostly limestone?

5. If you increased the time the materials were exposed to the solutions, what do you predict would happen?

6. What other experiments does this investigation suggest?

Earth Sciences

Soil descri(pH)tions

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Overview

Students learn how to take acidity measurements of soil in the field after rainstorms.

The activity provides the information to develop a packet of materials which can easily be carried into wilderness areas or on overnight camping trips or used in local environments.

Objectives

Through their experiences in this work, it is hoped that students will:

- understand that soil is not a static system, but continually adjusts in response to natural and human-made forces.
- improve their ability to use scientific equipment for extending the range of human senses.
- understand that the reaction of soils to acid inputs is complex.

Materials

The materials are described in terms of a packet for a person/small group to carry into a wilderness area. Each packet contains sufficient materials for determining the pH from at least five rain producing weather systems. The packet includes the following items:

Quantity	Item	Notes
1	Soil pH Instruction Sheet	Plastic laminated
1	Soil pH Data Sheet	Space for 10 samples
1	Hand Trowel	Plastic, garden tool
10	Plastic Bags	Zip lock, quart size
1	Case for Kit	Plastic, zip lock
1	Soil pH Kit	Hellige-Truog, #693
1	Pen	Permanent
10	Paper Towels	Absorbent
1	Map	Expedition area
1	Soil Horizons Data Sheet	Worksheet, draw and describe soil horizon boundaries and properties
1	E(pH)ects on Soil - An Experiment Data Sheet	Worksheet, experiments suggested by students

Teacher Preparation

1. Soil Profiles. This activity will be enhanced and much better understood if students are familiar with soil profiles.

   A trench dug into ground covered by vegetation will often reveal a succession of layers. At the surface there is a litter of dead or rotting plant parts, and underneath are one or more distinctly different layers that separate the surface litter from the subsoil. The layers are known as "horizons" by soil scientists. Sometimes they are very distinct; other times they are found to merge gradually one into another. The soil horizons formed as decaying plant parts are mixed with the upper layers of the mineral soil, and as drainage water percolated down through the litter and soil, slowly washing in and washing out chemicals.

   An idealized soil profile includes three horizons. The "A" horizons include organic particles such as litter, humus and the top of the mineral soil. This layer is continually being leached of various substances by water which percolates through it. The percolating water also physically removes fine soil particles and carries them downward. Underneath is a horizon of redeposition known as the "B" horizon. It is mostly colored mineral soil, but also includes humus layers and plant roots. Underneath are unaltered parent materials, which are called the "C" horizons. They consist of the underlying rock base, broken by frost or other deep weathering processes. They are essentially unaltered by leaching processes from above.

   There are a variety of subdivisions of these horizons, by which individual soils are described and defined. Consult a soils text or your local Soil Conservation Service representative for more specific information.

   As an introductory exercise on soils, examine a soil profile, either one prepared as a laboratory monolith or in the natural environment. If you can, try to study at least two soil profiles, e.g., one developed under forest and one under grassland vegetation. This will help students understand the relationship of soil profiles to the landscape. Students should record observations on the data sheet, "Soil pH."

2. A demonstration.

   Soil will fizz when drops of 10% H_2SO_4 are added to it. This is a simple test for free $CaCO_3$. Soils that fizz should have a high pH and be very resistant to the effects of acid precipitation. In this activity most of the work is to be done in the field. However, you may want to bring soil samples back to the lab where this simple test can be performed. The samples can be air dried before the test.

3. A note on map coordinates. Use latitude or longitude or have students arbitrarily mark off a map with X and Y coordinates. Use a metric ruler. The millimeter scale should be sufficient: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130...210, 220, 230, 240...n. A sample location could read: X:09; Y:235 or X09; Y235 or X-09; Y-235. You could also use the system found on road maps: H-9, A-14.

4. About collecting soil pH data. Soil pH data should be collected as soon as possible after a rainstorm. You might want to use the same sample site to record soil pH data before the rainstorm and, say, twenty-four, or possibly even forty-eight hours after.

5. Background. Soil plays a key role in ecosystems. It is one of the most stable components and, when combined with climate, defines a terrestrial ecosystem's productivity limits. Moreover, because much of the water entering streams and lakes directly contacts soil, soil properties also exert important influences on aquatic systems. Because of soil's importance to most ecosystems, the impact of acidic deposition on soils assumes considerable prominence in discussions of its potential effects.

   In considering the effects of acidic deposition, it is essential to realize that acids are produced naturally in humid temperate climates. Atmospheric acidic inputs must be viewed as an addition to natural, continual acidification and leaching processes due to carbonic acid formation, organic acid formation, vegetative cation uptake, and a variety of management practices.

The long-term effect (i.e., over decades or centuries) of acidic deposition can be expected to remove cations from forest soils, but it is not clear whether this will reduce available cations and enhance acidification of soils. The increased mobility of Al in uncultivated, acid soils is probably the most significant effect of acidic deposition on soils as they influence terrestrial plant growth and aquatic systems. Solubilization of Al (and heavy metals) can adversely affect groundwater and surface water environments. Biological alterations may consist of reduction and changes in populations of soil microbes and soil animals and influence their activity.

If acidic precipitation passes through soil before entering an aquatic ecosystem, it will usually be strongly influenced by the chemical nature of the soil. Even barren rock has some influence on the chemistry of runoff water. The pH of water leaving the soil is not necessarily the same as the pH of the soil solution in contact with the soil.

Teacher Guidelines

1. Divide the class into small work teams. Distribute and review the "Soil Descri(pH)tions Instruction Sheet" and the "Data Sheet: Soil pH" (two sides). Carefully review the procedure for collecting the soil samples and the instructions in the Hellige-Truog Kit for testing soil pH.

2. Select the sample collection stations and have students make measurements and record the data.

3. When the groups have completed their work, each group should report its findings to the rest of the class. After each group has presented the results of its research, the class should try to reach some conclusions based on the following kinds of questions:

   - What did you learn?
   - What evidence do we have? What additional evidence do we need?
   - What do we know? What don't we know?
   - How can we interpret the data we collected?
   - Were there any differences among the soil pH measurements collected? How do you account for the differences?
   - Soils are sometimes referred to as "nature's garbage heap." Do you agree or disagree? Why?
   - How would you decide whether a soil is polluted? What are some of the criteria for classifying particular additions to soil as pollutants? Is the ability of a soil to support plant growth a good criterion? How could you find out, i.e., what kind of an experiment could you do?
   - How would you interpret an experiment on soil that directly indicates an effect, e.g., change in pH, that used rain amounts exceeding natural precipitation? What experiment would you suggest? Why?
   - How would you interpret an experiment on soil that directly indicates an effect, e.g., loss of soil nutrients (soil ions), that used applications of concentrated acid (several kinds of artificial rain, with lower than normal pH)? What experiment would you suggest next? Why?
   - Give students a copy of "E(pH)ects on Soil - An Experiment." Hold a class discussion of their suggested experiments. This will help you help them focus attention on observations, quantification techniques (what to measure; how long to measure), identification and control of variables, experimental controls, and experimental design. It may suggest a project for a science fair or for your class.

SOIL DESCRI(pH)TION INSTRUCTION SHEET

All data are to be recorded in permanent ink on the data sheet.

A. Data Sheet, "Soil pH" (SIDE ONE)

1. Record your name, group name and address
2. Record sample number and date
3. Describe the soil sample site: location and vegetation. Provide as much detail as you can.

B. Data, "Soil pH" (SIDE TWO)

1. Record sample #.
2. Record date sample taken.
3. Record sample site location coordinates or attach map with location clearly marked.
4. Soil type (optional) - Consult Soil Conservation Service maps for soil type and record.
5. Precipitation pH - If known, record pH of most recent and average precipitation (See Acid Precipitation Awareness unit "Rain(pH)all")
6. Record pH of soil:

   a. Procedure:

      Non-Coniferous Forest Soils

      Carefully scrape away leaf mold, leaves, twigs and other debris from the soil surface. Use the trowel to remove samples of the organic humus layer (if present) and the surface mineral soil. (The latter should be removed from a depth of about 5 cm.) Place these samples in separate plastic mixing bags and label them. Don't mix the samples. Keep the trowel clean.

      Coniferous Forest Soils

      The leaf mold may be what to measure in coniferous forest soils. Use the trowel to remove samples of this layer and the surface mineral soil. (The latter should be removed from a depth of about 5 cm.) Place these samples in separate plastic mixing bags and label them.

      - o Thoroughly mix the soil in the bag until it is uniform. Remove any large clumps or pieces of debris.
      - o Follow the instructions found in the Hellige-Truog pH Kit and test the soil pH 3 times and record on the data sheet.

NOTE: If the soil is extremely wet or soggy, note this fact and use the following pH testing modifications:

- o Add soil to the test plate cavity before adding indicator
- o Compress the soil against the cavity's side with the spatula causing water to be forced to bottom of cavity
- o Blot out this excess water with paper toweling
- o Complete the pH test

7. Record soil texture (optional). Soil texture refers to the relative proportion of the various size groups of three individual soil particles: sands (2.0-0.05 mm.), salts (0.05-0.002 mm.), and clays (less than 0.002 mm.). Clays have mostly a platy structure. The relative proportion of each of these particles determine texture and textures determine soil response to use and manipulation. To become proficient in determining soil texture by the feel method requires practice.

Procedure:

- o Place a heaping spoonful-sized sample of soil in the palm of your hand.
- o Add water dropwise and knead soil with finger/thumb. Soil is the proper consistency when it is like moist putty. If soil is too wet, add dry soil to soak up water.
- o Try to roll a marble size sample into a ball.
- o Place ball of soil between thumb and forefinger, gently push the soil upward with the thumb, squeezing it into a ribbon. Try to extend ribbon over the forefinger until it breaks from its own weight.
- o Choose one of the following soil classes:

Forms ball and ribbon - Clay soil

Forms ball, but no ribbon - Loamy soil

Forms neither ball nor ribbon - Sandy soil

8. Record soil color. Soil colors may range from nearly white, through the reds, yellows, browns, or dark grays, to black. As examples, a soil may be described as grayish brown, i.e., brown modified by gray, while another soil is described as brownish gray, i.e., a gray, modified by brown. The color description may be further modified by the terms light or dark, i.e., light brownish gray or dark brownish gray.

9. Empty soil sample back into hole and replace debris, leaves, etc., or bring soil samples back to the laboratory for additional tests.

Name _____

Group Name _____

Address _____

_____ Zip_____

DATA SHEET: SOIL pH

(SIDE ONE)

I. Instructions: Complete this Data Sheet by following the directions outlined on the Instruction Card enclosed in this packet.

II. **SAMPLE LOCATION**

Sample # and Date	**Sample Site Description**
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

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(SIDE TWO)

Sample #	Date Taken	Site Location (Coordinates)	Soil Type	Rain pH	Soil pH Trial 1	Soil pH Trial 2	Soil pH Trial 3	Soil Texture Results	Soil Color	Soil Shade	Soil Wetness, (dry, moist, waterlogged)

Name _____

Class _____

SOIL HORIZONS

Using either a laboratory profile or in the natural environment, study a soil profile. Draw the horizon boundaries and note horizon properties.

Notes on Horizon Boundaries and Properties

There are five factors which play a role in soil formation. Try to describe each of them for this soil.

Geology (Parent Material) _____

Climate _____

Topography _____

Time (Age) _____

Vegetation and Biology _____

_____

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Name: _____

E(pH)ECTS ON SOIL - AN EXPERIMENT

You just got a job for a person who owns a small forested piece of ground. A stream runs through it into a small pond. The owner knows of the soil's importance to ecosystems. S/he has heard about acid rain and would like to know if there are any expected and potential effects from it.

Design an experiment to find out.

MATERIALS NEEDED

DRAWING OF EXPERIMENT (include descriptive notes)

What soil would you use? _____

What "rain" would you use? _____

What soil properties would you examine? _____

How would you test for effects? _____

Earth Sciences

A sul(pH)ate episode: 1976

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Overview

Widespread turbid air masses, sometimes referred to as "hazy blobs," are the most obvious characteristics of prolonged elevated pollution episodes. By using photographs taken from satellites, these large-scale pollution events, which may occur several times during a normal summer season, can be detected and tracked as they cross over land and ocean.

A major episode occurred from August 16-29, 1976, over substantial portions of the North American continent and north Atlantic Ocean. As the blob developed and dissipated over a twelve-day period, it extended as far westward as Kansas, southward through much of the Mississippi River Valley out over the Gulf, northward to James Bay, Newfoundland and beyond, and eastward, far out over the ocean.

In this activity students interpret some of the data from this episode and gain new perspectives on the magnitude of long-range air pollution transport.

Objectives

After completing this activity, students will be able to:

- describe how a weather system can affect and distribute air pollution from a local source to other areas.
- recognize that geographic location is no protection against atmospheric pollution.
- describe how atmospheric pollutants produced in the heavily industrialized Eastern United States, e.g., the Ohio River Valley, can be transported westwardly by upper atmospheric winds.
- discuss potential consequences of the long-range transport of pollutants by atmospheric processes.
- define, in their own words, long-range pollution transport.

Materials

Student Data Sheets-Map Series I-IV

Student Data Sheets-Hazy Blob Analysis Sheet

Teacher background

Sulfur pollution can be deposited in both its emitted form, sulfur dioxide, and as sulfate, after being chemically transformed in the atmosphere. Both forms can be deposited "wet" (i.e., by removal from the air during precipitation events--rain, snow, fog, dew) and "dry" (by the slow, continuous removal of gaseous and particulate sulfur oxides). Sulfate particles are believed to have a considerably larger average atmospheric residue than SO_2, and hence a larger range of impact.

As distance from the emission sources increases, the relative amount of sulfur deposited in each of these forms changes. Dry deposition predominates close to the emission source; wet deposition predominates in distant areas. It is estimated that these two processes deposit about equal amounts of sulfur when averaged annually over the Eastern United States. Both wet and dry deposition contribute to the acidity received by ecosystems.

The best documented and best understood effects of acid deposition are those on aquatic systems. The sensitivity of a lake or stream to acid deposition depends largely on the ability of the soil and bedrock in the surrounding watershed to neutralize acid. When the soil is very thin or has little neutralizing capacity, or where the terrain is so steep or rocky that rainfall runs right over it, the bodies of water within a watershed are at risk. When the waters of a lake or stream become more acidic than about pH 5, many species of fish die and the ecosystem changes dramatically. This may be due to the acidity, to the metals (especially aluminum) released under acidic conditions, or to a combination of both.

In addition to the acidification of aquatic ecosystems, transported air pollutants have been linked to harmful effects to terrestrial ecosystems. Broad forested areas subjected to elevated levels of acid deposition, ozone, or both, have been marked by declining productivity and dying trees, although it is uncertain how much of this is due to airborne pollutants.

Transported air pollutants adversely affect agricultural productivity. Up to 90 percent of the damage to crops from air pollutants may be due to ozone. Large areas of the United States, including much of the Midwestern Corn and Soybean Belts, are exposed to high levels of ozone. Ozone is thought to cause about a 6-to-7-percent loss of U.S. agricultural productivity.

Teacher guidelines

1. Students can work alone or in small groups. Give copies of Map Series I-IV and the Hazy Blob Analysis Sheet to students and go over the map background information with them. Clarify any ambiguous terminology.

2. When students are finished, use the questions on the Hazy Blob Analysis Sheet as a basis for discussion.

   The discussion may lead to a review of sulfur pollution. Some general information you can point out is found in the teacher background.

   You may want to point out how a technology-meteorological satellite has helped us understand basic atmospheric physical processes and long-range pollution transportation. Satellites have provided a new and revealing way of visualizing air pollution episodes. At one time air pollution was regarded as a "local" phenomenon, i.e., the air pollution at one point represented emissions from a small geographic area (e.g., several countries) being added to "natural background" pollution.

However, satellite imagery, when combined with a variety of quantitative weather and chemical data, has revealed that air quality can be degraded on the scale of an entire (and large) air mass. The data from satellites plays and important role in determining the geographic extent of air pollution episodes.

The haze detected by satellites consists of a complex of water droplets, atmospheric pollutants and dust. Many of the chemical reactions that contribute to the haze are not completely understood.

3. Conclude this investigation with a discussion of "downwind".

   - What does downwind mean?
   - Tell students that a Canadian publication on acid rain is titled "Downwind."
   - In this episode, what states are downwind? Is Canada downwind?
   - Are some states more downwind than others?
   - In some sense do we all live downwind?

4. As an application activity have students clip newspaper and magazine articles on the regional distribution of acid rain air pollution. Ask students to identify, by circling, the pollutants of concern, the risks from transported air pollutants, and disagreements over values.

HAZY BLOB ANALYSIS SHEET

MAP BACKGROUND

MAP SERIES I-III were made by using data from several sources. These include: 1) satellite photos taken at an altitude of about 25,000 miles; 2) standard U.S. weather data; 3) airport observations; and 4) air pollution monitoring sites.

Standard weather map symbols are used to show the locations of high and low pressure systems and frontal systems on the SURFACE WEATHER AND VISIBILITY map.

The map, AIR PARCEL ROUTES FOR PREVIOUS THREE DAYS, shows the paths followed by individual air parcels. The arrows can be thought of as the tracks of balloons simultaneously released into the air mass. The arrow shows the position of the air parcel at noon of the day indicated and its previous seventy-two hour path.

The SULFATE map shows 24-hour sulfate concentrations for those areas where there is monitoring equipment. μgm^{-3} means micrograms per cubic meter. In the 1970s the annual average concentration of sulfates for the eastern United States was 5-15 μgm^{-3}. (Because of the way the sulfate monitoring equipment works, no data were available for the majority of the region on August 22.)

The OZONE map shows those areas where the ozone value was greater than 80 parts per billion (ppb). Ozone is an odorless, very active form of oxygen that can damage field crops and forest trees. It may also interact with acid rain to cause damage to vegetation.

The SENSITIVE map in MAP SERIES IV was derived primarily from studies of soil and bedrock characteristics. The EMISSIONS map is based on distribution of coal-fired power plants and industries, the quantity of SO_2 emissions produced per year, and SO_2 monitoring data.

QUESTIONS

1. Describe the general wind circulation pattern around a high pressure air mass. What is your evidence? _____

2. Where is the center of the high pressure cell located in MAP SERIES I? _____
_____

3. What evidence do you find in MAP SERIES I that the initial phases of air stagnation are in progress? _____

4. In MAP SERIES II where is the center of the high pressure cell located? _____
_____

5. a. Based on two pieces of evidence--the location of the high pressure cell on August 16 and 22--would you describe this as a stagnant air mass? _____ What is your reason? _____

   b. What additional evidence can you find that supports or modifies your answer to 5a? _____
_____

6. How does the system in MAP SERIES II act to further intensify and worsen air quality? _____
_____

7. What is the reason that air masses such as that shown in MAP SERIES II are sometimes referred to as "hazy blobs"? _____

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8. a. What evidence is there in MAP SERIES III that the "hazy blob" is beginning to break up?

b. What direction is it moving in?

c. Where will this take this air?

9. As visibility is reduced, what happens to sulfate concentrations? What is your evidence?

10. Do these maps provide evidence that air quality can be reduced (degraded) on the scale of an entire air mass? What is the evidence?

11. At its full development extreme, what states are affected by this weather episode?

12. In the latitudes between Texas and Minnesota the wind direction is under the control of the Prevailing Westerlies. During the air pollution episode described on these maps, what is the general direction of the wind in the midwest? How do you explain this?

13. Do these maps provide visible evidence of long distance transport of air pollution? Explain your answer.

14. Do these maps provide evidence of a relationship between the development of a hazy blob and producers of SO_2? What is it?

15. a. Examine the SENSITIVE map in MAP SERIES IV. What does this evidence mean?

b. How is it related to the other pieces of evidence you have been examining?

16. One popular definition of ecology says that "everything is connected to everything else". What are all the possible connections?

Earth Sciences
Physical Sciences

Bedrock com(pH)osition

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Overview

Acid precipitation has had devastating effects on some lakes in various parts of the United States. Why is it that some lakes are more affected by acid precipitation than others? In this activity different types of lake basins are simulated and the influence of acid rain is determined for each of them. Based on the data collected, students construct an explanation about the ability of a lake to neutralize acidic deposition.

Objectives

After completing this activity, students should be able to:

- o identify the variables.
- o collect and organize data in tables.
- o describe an analytic measure used in evaluating acidification of surface waters.
- o describe an interaction between abiotic factors.
- o describe the influence of geological terrain on the sensitivity of aquatic systems to acidic deposition.

Materials

For each student or student team:

10% H_2SO_4 in dropping bottles
pH indicating paper
100 gm. $CaCO_3$ (crushed marble/ limestone)
100 gm. crushed granite
1 beaker, 1L
3 beakers, 400 mL
1 stirring rod
1 medicine dropper
1 graduated cylinder
Masking tape/wax pencils
Safety goggles
Data Sheet, "Basin Basics"
Data Sheet, "Lake Experiments in Nature"

Teacher Background

To understand the effects of acidic deposition on aquatic systems requires more than this simple experiment. You can use this work to help students understand that judgments in science are never final or absolute. In science we operate on what seems most probable, on the basis of our data, and on our knowledge. An experiment or a report by someone else often suggests new variables which require new investigations.

Aquatic systems may be thought of as receiving systems that consist of terrestrial components (forest, crop or grass canopy cover; litter layer; organic soil layer; inorganic soil layer; bedrock), wetland components (vegetation; water-stream, pond, swamp, bog, fen), and aquatic components (stream, lake, sediment). The interactions of acid deposition with all components must be evaluated before the net effects of acid deposition can be determined.

The three parts of the aquatic receiving system are linked, so the effects of atmospheric deposition on one component can cause secondary effects in another component. The hydrologic pathway controls which components are affected by (or linked to) other components. Precipitation may first hit the canopy, then travel through successive layers of the terrestrial system before it enters wetlands adjacent to the terrestrial system and then finally the lake. This means that the effect of acidic deposition on aquatic systems depends on the quantity and quality of atmospheric deposition and its effects on all components of the terrestrial and wetland systems that it contacts prior to discharge into the aquatic system.

The composition of aquatic systems is controlled not only by physical and chemical processes, but also by biological processes. The biological component can make waters more sensitive, less sensitive, more acidified, or less acidified.

Furthermore, five factors must be considered when we assess the role of atmospheric deposition in the acidification of aquatic and terrestrial ecosystems. These are the wet and dry components of atmospheric deposition, the rate of input, the location of deposition, and temporal distribution of deposition (episodic, seasonal, annual).

This activity focuses on the location of deposition. Wet deposition of acidic substances is well measured in most areas of North America where the geological terrain has a low capability to neutralize acids and where wet deposition is known to be relatively high.

Teacher Guidelines

1. Familiarity with the effects of acid rain, particularly on aquatic systems, should be developed prior to this work. The effects of acid rain on lakes and streams, with accompanying biological damage, has been widely acknowledged. Assessing and determining causal relationships remains difficult because of interrelated chemical, physical and biological processes in ecosystems.

2. Distribute copies of "Basin Basics" and review your specific laboratory procedures with students and any changes in the procedures. It is strongly recommended, and in some states required, that you and your students wear safety goggles during this investigation.

3. When students have completed the work, use the questions found on "Basin Basics" as a basis for discussion and summarizing the lesson. After this, hold a class discussion focusing on what other laboratory experiments this investigation suggests.

4. Optional. A sheet, "Lake Experiments in Nature" is included. Use it if you think it will help students identify environmental factors, correlations between bedrock types and acid precipitation, and relate environmental factors to lake chemistry.

EXTENSION ACTIVITIES

1. Repeat the investigation using different "lake bottoms":

   - glacial till, sandstone, quartz sandstone, shale, dolomite, conglomerate, fossiliferous sediments, carbonate-cemented, carbonate interbedded, or carbonate clastic sedimentary rocks.

2. Compare the effects of materials with different effective reaction surface areas.

3. Can egg shells beat acid rain? This possibility is being investigated in Sweden. Lake Holmsjo in central Sweden is being treated with egg shells discarded from a large bakery. Have students devise some other ways to "recover" their "lakes." How well do recovery schemes work? What are their advantages and disadvantages?

Name(s) _____

Class _____

BASIN BASICS

Procedures:

1. Put 900 mL of tap water in a 1L beaker.

2. Check the pH of the water.

3. Carefully add drops of 10% H_2SO_4 solution. The number of drops will vary, but a rough rule of thumb is 25-30 drops. Be sure to stir the solution thoroughly while adding the drops of H_2SO_4 and check the pH frequently. This is a tedious process, but it must be done accurately. When the solution reaches pH 4, stir the solution, wait one minute, and then check, pH 4. If needed, add H_2SO_4 to establish the correct pH. Follow the same procedure until a stable pH is established. This may take several minutes.

4. You will need three 400 mL beakers.

   a) Place 100 grams of marble in a 400 mL beaker

   b) Place 100 grams of crushed granite in a 400 mL beaker

   c) Place no materials in the third beaker

5. Label each beaker.

6. Add 300 mL of the pH 4 "acid rain" solution to each of the three beakers. (Before you add the "acid rain," you may want to re-check the pH. Does it still have a pH of 4?)

7. Measure and record the pH for each solution. Record any observations.

8. Make a prediction (or hypothesis) about what you think will happen to the pH in each of the beakers.

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9. Let the three beakers stand overnight. Record the pH of each solution the following day and any observations. Repeat daily for one week. Design a table for recording the data.

ANSWER THESE QUESTIONS:

1. Variables present in an experiment include:

   a. Manipulated Variable. This is the variable that is deliberately changed in an experiment. What is the manipulated variable in this problem?

   b. Responding Variable. This is the variable that changes as a result of manipulation. What is the responding variable in this problem?

   c. Variable(s) Held Constant. The variables that are kept the same while the investigator is manipulating one variable and observing the response of another. Name all the variables that need to be held constant in this investigation.

2. Identify and name variables which were not held constant in this investigation.

3. Name the variables that might affect the responding variable.

4. Construct a graph of pH for all three beakers on the horizontal axis. Sketch in lines. Label each axis and give the graph a descriptive title. What was the pH for each beaker on day 3?

5. Substances with the properties of acids can lose those properties when mixed with certain chemicals. This process is called neutralization. In the following table, use a check to indicate whether there were any changes in the solutions, and an N to indicate a neutralization reaction.

Beaker	Change	Neutralization

6. Is there any evidence of a chemical change in any of the three beakers? If so, describe your evidence.

7. What might cause a rock to have the ability to neutralize an acid?

8. Consider each of the beakers a lake basin. What can you say about the influence of the geological terrain on lake chemistry?

9. What do you have questions about?

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Name _____

Class _____

LAKE EXPERIMENTS IN NATURE

Rain - pH 4.2

1. Rank order the lakes from most likely to be affected (1) to least likely to be affected by acid rain (3).
2. What is your evidence?
3. Which lake could have a neutral or even alkaline pH?
4. What is your evidence?
5. What factors in the environment might affect the pH of the lakes?

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Physical Sciences

Anthro(pH)ogenic emissions

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Overview

Students consider some of the connections between the sulfur found in a fuel (soft coal) and acidic and acidifying substances in the atmosphere. This activity can be used as either a demonstration or a student laboratory investigation.

Objectives

After completing this activity, students should be able to:

- give an example of an acidic/acidifying substance in the atmosphere and know that it is produced by human activities.
- describe, in simplified form, the chemical transformation process by which a common pollutant becomes more acidic in the atmosphere.
- recognize that after chemical reaction in the atmosphere, sulfur oxide pollutants can result in deposition of acidic matter.

Materials

For each team:

Gas Generating Bottle, 250 or 500 mL
Glass Plate/Aluminum Foil/Notched Cork
Deflagrating Spoon
Watch Glass/Test Tube
Phenolphthalein
0.05 N NaOH
Bunsen Burner
Soft Coal
pH Indicator Paper, Red and Blue
Distilled Water
Marble/Limestone Chips
Medicine Droppers
Laboratory Safety Goggles
Beakers
Stirring Rod
Anthro(pH)ogenic Emissions - Laboratory
Anthro(pH)ogenic Emissions - Demonstration

Optional:

Sulfur
Wood/Wood Splints

Teacher Background

Acidic and acidifying substances in the atmosphere may be produced by natural or by human (anthropogenic) activities. In either case, emissions become available for transport to other locations, for combination with other atmospheric substances, and for deposition on surfaces.

There are many questions about emission sources. One of these, for sulfur, is whether the natural sources are significant, and, if so, where are they and how do the emission rates vary seasonally? On the other hand, concerning anthropogenic sources, how have historical trends in fuel use changed emission rates and how are future trends likely to alter the rates?

There are many problems remaining in understanding the natural sulfur cycle and also a number of unknown factors. However, for land areas it is thought that the most important natural sources of sulfur compounds are emissions resulting from biological actions in the soil. On a global basis, emissions of sulfur from volcanoes may also be significant.

Specifically in the United States east of the Mississippi River, the emission rate from soil sources increases with ambient temperature and in coastal wetlands. There is rapid increase in the emission rate of sulfur compounds from the soil from north to south. Central wetlands, although covering only about 7 percent of the land area, have an average emission rate of about 10 times the rate of inland soils. However, they account for only about 1 (one) percent of the natural sulfur emissions east of the Mississippi River.* Present evidence does not show that natural sources of sulfur compounds are significant contributors to excessively low precipitation pH when compared to human sources.

Large quantities of sulfur (and nitrogen) oxides are discharged annually into the atmosphere from the combustion of fossil fuels such as coal, oil, and gas. Through chemical reactions in the atmosphere, these pollutants can be transformed into acids, which can return to ground level as components of either rain or snow. The deposition of these acids has been associated with terrestrial, aquatic, and materials effects.

Sulfuric acid (H_2SO_4) represents a small fraction of the SO_2 emissions and exists as a vapor in combustion emissions. Upon mixing and cooling in the atmosphere, the acid condenses as free particles. Field measurements have shown that a larger fraction of SO_2 is emitted as H_2SO_4 from oil combustion than from coal burning.

*U.S.E.P.A. 1984, The Acidic Deposition Phenomenon and its Effects: Critical Assessment Review Papers. Vol. 1, EPA 600/8-83-016 AF Office of Research and Development, Washington D.C.

In recent years, electric utilities appear to have contributed to more than half of the total sulfur oxide emissions. Highest SO_2 emissions occur in the Midwest and within a 31-state region, the five highest levels of estimated SO_2 emissions for 1980 occurred in Ohio, Indiana, Pennsylvania, Illinois and Missouri. (The areas of highest emissions densities shifted from the North Atlantic Central region in the 1950s to the Midwest in the 1970s.)

Sulfur (S) occurs in the atmosphere (troposphere) in diverse forms involving oxidation states from -2 (H_2S) to +6 (H_2SO_4). Some aspects of the chemical mechanisms of SO_2 oxidation are not well understood; the final product is a sulfuric acid aerosol.

In general, deposition from a pollutant source is greatest near the source and decreases more or less exponentially away from the source. In the summer, on the average, well over half of the eastern U.S. sulfur emissions may be deposited within two days and 500 km. from the source. The transport range is likely to be considerably greater in winter. The prevailing flow of the pollutant is referred to as downstream. In the ecologically sensitive regions of eastern North America, downstream generally means toward the east/northeast.

Teacher Preparation

1. Laboratory safety. It is strongly recommended that you do not do this work, either as a demonstration or as a student activity, unless you and your students wear eye protection. It may be required in your state. There is a general rule. When you work with chemicals: Wear Safety Goggles! The work involves a flame and an acid.

   When generating a toxic gas such as sulfur dioxide in the laboratory, use a fume hood. The hood should not be used for chemical storage. The room should be well ventilated.

2. Litmus paper. A large supply of litmus paper can disappear in a hurry. Pre-cut litmus to appropriate lengths (1 cm.) or make your laboratory instructions very clear.

3. The solution which results from burning the soft coal or sulfur is a weak acid and may not always be strong enough for dramatic changes, e.g., bubbles to be observed when it is added to pieces of marble. Use as large a gas generating bottle as you can and also make a back-up. You can also try oxidizing the solution with a few drops of H_2O_2.

4. This activity can be done as either a student laboratory investigation or as a class demonstration. The teacher guidelines (see below) are written in the form of a student laboratory investigation. The student investigation is slightly different from the teacher demonstration. If you choose to use the activity as a class demonstration, a brief description of materials and procedures follows.

   Demonstration Materials - Teacher

   Bottle, large mouth, 500 mL
   Glass plate/Aluminum foil/Notched stopper
   Soft coal/Sulfur
   Universal indicator solution (Appropriate acid-base indicators may be substituted, pH range 4-7).
   Deflagrating spoon
   Bunsen burner

   Demonstration Materials - Student

   Watch glass/Test tubes
   Marble/Limestone chips
   Litmus paper, blue and red
   Data sheet, "Anthro(pH)ogenic Emissions - Demonstration"

   Demonstration Procedures.

   a. Give students a copy of "Anthro(pH)ogenic Emissions - Demonstration" and review it with them.

   b. Add about 50 mL of distilled water and 1-2 drops of the indicator. (You can use tap water which, because it is more alkaline than deionized water, gives a very nice color change. Indicators may have to be adjusted slightly with a weak acid or weak base to obtain the appropriate color.)

   c. Place a lump of soft coal in a deflagrating spoon and heat over a Bunsen burner until it ignites. (Sulfur, 1 gram, may be substituted.) Quickly insert the spoon into the gas bottle and cover the mouth of the bottle as tightly as possible.

   d. After the coal stops burning, remove the spoon. Do this as quickly as possible. Re-stopper the bottle. Shake/swirl the bottle for 2 to 3 minutes. (You may want to repeat the demonstration to encourage more detailed observation or for additional solution for the rest of the work.)

   e. Divide the class into small teams and have them investigate the effects of the solution on the marble chips. Each team will need about 10 mL of the solution.

   f. Summarize the demonstration by reviewing the questions and observations on the data sheet, the chemistry of the demonstration and the chemistry of acid rain. Now, hold a class discussion. Use the following kinds of questions to guide the discussion:

      - A chemical change is a change in matter that cannot be reversed by physical means. What are some observations you made that would indicate chemical change?
      - A physical change is a change in matter that can be reversed by physical means. Are any of the changes in this experiment physical changes? What could you do to test such a hypothesis? (What does it mean to reverse a change by physical means?)
      - What are some variables which might affect the outcome of this experiment? What experiments do they suggest?
      - What are some things you have learned about acid rain?
      - What are some possible effects of acid rain on the environment?

Teacher Guidelines

1. Give students a copy of the "Anthro(pH)ogenic Emissions - Laboratory" sheet, and go over the laboratory procedures, including laboratory safety, with them.

2. When students have completed the work, have groups report their findings and results. Use the laboratory as a basis to discuss the chemistry of the reactions and to explore the connections between the work and acid rain.

EXTENSIONS

1. Prepare the SO_2 gas with "lakes with a variety of bedrock materials," for example, granite, limestone, shale, or sand.

2. Compare the SO_2 gas with gases prepared from burning wood or charcoal.

3. Place a flower petal (or flower parts) into a test tube and cover it with a test solution. Record all observations.

4. Compare the effect of the temperature of the water. Does it make a difference? Is the SO_2 generated more soluble in very cold water than it is in warm water?

5. Examine the embrittlement of paper. Is it accelerated by exposure to acidic deposition? Samples of different kinds of paper can be exposed to sulfur dioxide. (You do not need water in the gas generating bottle.) The trick will be to try to assess resulting damage (coloration, strength, foldability, writing quality).

Name(s): _____

Class: _____

ANTHRO(pH)OGENIC EMISSIONS - LABORATORY

Before you do the work, note any changes in the procedure and list the materials you need.

Materials

Drawing

this is where drawing goes

PROCEDURE

Part A.

1. Place about 15 mL of distilled water in a gas generating bottle.
2. Test with litmus paper. Record the results. (Touch a clean stirring rod to the water and the paper.)
3. Place a lump of soft coal in a deflagrating spoon and heat over a Bunsen burner until it ignites.
4. Insert the spoon (with the burning coal) into the gas generating bottle and cover the mouth of the bottle with a glass plate/aluminum foil/notched cork. Cover the mouth of the bottle as tightly as you can.
5. Hold the spoon above the water and let the coal burn until the coal stops burning.
6. Remove the spoon, keep the bottle tightly covered and swirl it for 2-3 minutes.
7. Test with litmus paper. Record the results.

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Part B.

1. Pour about 5 mL of the solution you made into a watch glass. Test the solution with litmus paper. Record the results of this test. Now, place a few marble chips on the watch glass.

2. Carefully observe the chips for 5 minutes. Record all observations. After 5 minutes, test the solution with litmus paper. Record the results of this test.

Part C.

1. Place 10 mL of distilled water in a beaker.

2. Add one drop of phenolphthalein solution to the distilled water in the beaker and to the solution in the gas generating bottle.

3. Add drops of NaOH solution to the distilled water and to the solution in the gas generating bottle until there is a color change. Record all data you collect.

OBSERVATION QUESTIONS:

1. Acids belong to a group of substances with a set of common properties. Based on your observations and the data you collected, did you make an acid? _____ What is your evidence?

2. Did the pH of the water in the beaker and the water in the gas generating bottle increase, decrease, or stay about the same? What do these findings mean?

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3. For each part of the investigation, record all evidence of interaction.

A.

B.

C.

4. Scientists frequently use laboratory experiments as models of what goes on in the natural/human environment. Think of this laboratory as a simulation of conditions in the environment.

A. What was simulated? _____

_____

_____

B. Is this investigation a useful model of what may be occurring outside the laboratory? Why or why not?

_____

_____

_____

C. What relationships have you discovered in this experiment that contribute to your understanding of what may be occurring in the environment?

_____

_____

D. What are the limitations of the evidence you found about what is occurring in the natural and human environment?

_____

_____

_____

E. What other experiments does this investigation suggest?

_____

_____

_____

Name: _____

Class: _____

ANTHRO(pH)OGENIC EMISSIONS - DEMONSTRATION

1. Record all your observations during the demonstration.

2. Is the gas produced soluble in water? What is your evidence?

When sulfur is heated, a suffocating choking gas results. Write balanced equations to represent the sulfur reactions in this demonstration.

3. Obtain a watch glass, litmus papers, and marble chips. Your teacher will add a few mL of the solution to the watch glass. Test the solution with litmus paper. Now place a few marble chips in the watch glass. Carefully observe the chips for about 5 minutes. Note all observations. At the end of 5 minutes, test the solution with litmus paper.
NOTES

Evidence of interaction:

Write a balanced equation for the reaction between the marble chips ($CaCO_3$) and the solution.

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Bu(pH)ers: Resisting change

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Overview

Students investigate two buffer systems. They learn that a substance has buffering capabilities when, coming into contact with a solution that contains acids or bases, it neutralizes the acids or bases without appreciably changing its own nature.

Objectives

Through their experiences in this work, it is hoped that students will be able to:

- describe the effects of acids and/or bases on buffered chemical systems.
- define a buffer.
- discuss the effects of acid rain on buffered and unbuffered aquatic systems.

Materials

Equipment:
- test tube rack
- 15 x 125 mm test tubes
- 50 ml beakers
- 10 ml graduated cylinders
- Pipet, medicine dropper
- stirring rods
- washing bottles
- pH test papers, red and blue

Stock Solutions:
- 1.0 M HCl (86 ml conc. HCl)
- 1.0 M NaOH (40 g NaOH)
- 1.0 M $NH_4C_2H_3O_2$ (77 g $NH_4C_2H_3O_2$)
- 1.0 M $NaHCO_3$ (84 g $NaHCO_3$)

Indicators:
- Methyl orange (0.1 g/100 ml soln.)
- Alizarin yellow R (0.1 g/100 ml soln.)

Data Sheet: Resisting Change

Teacher guidelines

1. Distribute copies of "Resisting Change". Briefly review the laboratory and note any changes in the procedures.

2. Discuss the laboratory work and use the questions on "Resisting Change" as a basis for a class discussion.

3. Discuss buffers and buffering capacity with your students. Include some of the following points in your discussion:

   - Review the chemistry involved in this investigation.
   - The process of adding successive portions of one reagent to a fixed amount of another reagent is called titration.
   - A solution of a weak acid and its salt or that of a weak base and its salt will resist a change in pH, even when considerable acid or base is added. Thus, the concentration of hydrogen ions present will change very little in a solution of acetic acid containing a relatively high concentration of sodium acetate. Such a solution is said to be "buffered" against pH change.
   - A buffer is a substance in solution capable of neutralizing both acids and bases and thereby maintaining the original pH of the solution.

- Buffering capacity is the ability of a body of water (and its watershed) to neutralize introduced acid.
- You may want to briefly discuss the chemistry of lake buffering and acid rain. A lake may be thought of as a solution of bicarbonate. As acid precipitation is added there is little change in the pH until most (80 - 90%) of the bicarbonate in the lake has been consumed, i.e.,

  $H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow H_2O + CO_2$

  In this reaction, the bicarbonate is converted into carbon dioxide and lost to the atmosphere. The decrease in the pH value is very small in proportion to the amount of acid added. It is not until the bicarbonate is exhausted that the solution will become strongly acid. This is the process you observed in the laboratory immediately after the end point is reached. Whether a lake will become acidic or not depends on the interaction between the rate at which acid is added to the lake, the composition of the bedrock, and geochemical weathering processes which replace the bicarbonate.

  In general, buffer action is exhibited by ions of weak acids or bases. Strong acids and bases are almost completely dissociated in water and have no reservoir of undissociated acid or base. Strong electrolytes are essentially completely ionized in aqueous solution (e.g., HCl, HNO_3, NaOH, KOH, etc.). Weak electrolytes are only partially ionized in aqueous solution and yield a mixture of the undissociated compound and ions.
- Acidification is a defined as the loss of alkalinity. Those aquatic systems for which acidic deposition may cause acidification or loss of alkalinity to levels that result in biological change are termed sensitive. Non-sensitive systems may, therefore, experience a loss of alkalinity (i.e., acidification) but are unlikely to experience any major biological effects. The use of the term acidification does not automatically imply acidification as the result of acidic deposition.

  Loss of alkalinity can be either chronic (long-term acidification) or acute (short-term acidification). Short-term acidification refers to the development of strong acidity during acid episodes (e.g., spring snowmelt) lasting for periods of days or weeks. Long-term acidification refers to the gradual loss of alkalinity over periods of years or decades.

4. Summarize this laboratory investigation by making the connection between the work and the effects of acid rain on aquatic systems. Use these kinds of questions as a basis for discussion:

   - How would you define a buffer? Ask students to define it two ways: a) operationally by giving a set of directions for what should be done experimentally to test the state (i.e., what to do to find out whether a solution is a buffer), and b) conceptually (i.e., what to think about when thinking about a buffer).
   - What are the hazards posed by acid rainfall to an unbuffered lake?
   - Are buffered lakes completely protected from the effects of acid rain? What is the reason for your answer?
   - Scientists who study water (limnologists) insist that the pH measurement of a lake must also be accompanied by another measure: the buffering capacity. What purpose does this measurement serve?

NAME(s)_____

CLASS_____

RESISTING CHANGE

GATHERING DATA

Part I.

A. Add 5 mL of 1.0 M ammonium acetate solution to one clean, dry 15 x 125 mm test tube and 5 mL of distilled water to another similar test tube.

B. Test each solution which litmus paper.

C. Add 2 drops of methyl orange indicator solution to each substance.

D. Obtain a small amount of 1.0 M HCl solution.

E. Add 1.0 M HCl, drop by drop with a medicine dropper, to the ammonium acetate solution. Count the drops you add. As you add drops, thoroughly and continuously stir the solution. Continue adding the acid solution until the solution is a permanent reddish color. This is known as the end point. Note: This work should be done against a white surface so that color changes can be spotted quickly.

F. Test each solution with litmus paper.

G. Repeat steps E and F for the distilled water sample.

H. (Optional). Test the buffering action of the ammonium acetate solution against the addition of a base. Use 1.0 M NaOH solution and alizarin yellow R indicator solution.

I. In the table below record the solutions and your data.

Part II.

A. Add 5 mL sodium bicarbonate solution to each of two clean, dry 15 x 125 mm test tubes.

B. Divide this into two 5 mL portions in separate 15 x 125 mm test tubes.

C. Test each solution with litmus paper.

D. To one sample, add 2 drops of alizarin yellow R indicator solution. Then add drops of 1.0 M NaOH solution until the end point is reached (yellow).

E. To the other sample, add 2 drops of methyl orange indicator solution. Then add drops of 1.0 M HCl solution until the end point is reached (orange-red).

F. Test each solution with litmus paper.

G. In the table below record the solutions and your data.

5 mL of Various Solutions	Begin Reaction to Litmus Paper	Indicator Solution	Acid/Base Added	Drops Added	End Reaction Litmus Paper

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QUESTIONS

1. Which system changed the most? The least? What is your evidence?

2. What is the purpose of the distilled water sample in Part I?

3. Should a similar sample of distilled water have been used in the investigation in Part II? Why or why not?

4. In Part I, would you expect any difference in outcomes between distilled water that has been in contact with air and distilled water which has been boiled?

5. Is there any evidence for a chemical change in any of the systems investigated? If so, specify.

6. On the basis of your data, what conclusions can you draw?

7. What are some sources of error in this investigation? What are some ways they could be reduced?

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Physical Sciences

$N=10^{x}$: Making ten(pH)old increases in acidity visible

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Overview

It is not possible to discuss, read, or learn about acid precipitation without running into the symbol, pH. The "p" refers to the Danish word potenz (power) and the "H" stands for the hydrogen ion - the thing which makes an acid active.

Most pH scales in books and brochures about acid precipitation treat pH as though it were a simple, linear measure. It is not. The pH scale is logarithmic: a pH of 6 has 10 times more hydrogen ions than a pH of 7; a pH of 5 has 10 times more hydrogen ions than a pH of 6, and 100 times more hydrogen ions than a pH of 7. In this activity, students make the pH scale visible and, hopefully, gain some new insights into the nature of a logarithmic scale and pH.

Objectives

Through their experiences in this work, it is hoped that students can:

- describe and use a measurement technique for pH.
- place particular substances on a pH continuum.
- describe how a pH scale is numbered.
- better understand that each change of one pH unit represents a tenfold change in acidity.

Materials

For each small group:

1 ball of string/thread/yarn
1 meter stick/metric ruler
Masking tape

Teacher Preparation

If students use a cm. scale and if you are interested in pushing this activity to its limit (especially if you want students to see the dramatic expansion of the logarithmic scale below pH 4), you will need the great outdoors: a pH of 3 requires 10,000 cm., a pH of 2 requires 100,000 cm., etc.

By using millimeters (mm) and going only to a pH of 2, you can probably do this in your room or a nearby hallway: the scale will be 10 m. long. As one teacher said: "long enough, but still under control."

If you use cm.'s, have students measure 1 cm. from the end of the string and label it pH 7. After students have completed the unit, ask them to locate pH 8, pH 9, and pH 10. (8 = 0.1 cm.; 9 = 0.01 cm.; 10 = 0.001 cm. from the origin)

Teacher Guidelines

1. Introduce this lesson by asking students what they have read in newspapers or magazines, seen on television or heard on the radio recently about events associated with pH. Take five or ten minutes to discuss the events they identify. Here are some questions which will help guide this discussion:

   - What is the common name for atmospheric-related pH events?
   - Where did the pH-related events occur?
   - What kinds of chemicals are involved? Where do these chemicals come from?
   - What does pH mean?
   - What are some of the effects thought/known to be associated with the pH-related events?
   - What is being done to resolve these problems?

2. Next, explain to students that this lesson is designed to help them better understand the concept of the pH scale. Divide the class into small groups and give them a copy of "The pH Scale: An Exercise in Units." In Section I, students quickly review the standard pH scale. In Section II, students make a logarithmic scale. Review the instructions and assignments with your class. Assign the activities and questions that are appropriate in terms of your curricula and students.

3. pH and interval lengths are listed below in both centimeters and millimeters.

pH	length of interval (cm.)	length of interval (mm.)
7	1	1
6	10	10
5	100	100
4	1,000	1,000
3	10,000	10,000
2	100,000	100,000
1	1,000,000	1,000,000

4. Students are asked to locate a variety of substances on their string scale. To do this, they need to know that for each 0.3 of an increase in pH, the length of the interval on the string doubles or for 0.3 of a decrease in pH, the length of the interval on the string halves. Some of these relationships are found on the overhead transparency, "Interval Lengths and Acidity." Encourage students to examine this information carefully before they use it.

5. Conclude the lesson by discussing the questions asked on "The pH Scale: An Exercise in Units." Be sure to review some of the key points raised in this investigation.

   Some additional questions you can ask might be:

   - What was the purpose of this investigation?
   - What is important to know about the pH scale?
   - If the "scale" of the pH scale such as the one shown in Section I of your laboratory sheet, is wrong, what are some reasons such a scale is used?
   - The pH of "normal rain" is 5.6. How would you define "acid rain"? (You might want to point out to students that if pure water is exposed to air, the acidity increases. This is because some carbon dioxide in the air dissolves to form carbonic acid. The pH of such a solution would be about 5.6. For this reason, 5.6 is often considered to be the normal pH of rain. There are natural acidic sources that can cause rain to have a lower pH, e.g., sulfur dioxide released by volcanoes. There are also natural alkaline substances that can neutralize rain and even raise the pH e.g., ammonia, calcareous dust. The question of what is the normal pH of precipitation is, therefore, debatable.
   - To what does the term pH refer?

SOME BACKGROUND: pH

The acidity of any solution, including rain or snow, is measured on a scale known as a pH scale. This scale is numbered from 0 to 14. A pH value of 7 is neutral, neither acidic nor alkaline. Values lower than 7 are more acidic - vinegar, for instance, with a pH of between 2.4 and 3.4. Values above 7, such as for ammonia or lye, represent alkalinity.

The pH scale is a logarithmic measure, that is, each change of one pH unit - say from 6 to 5 - represents a tenfold increase in acidity. Thus a drop from pH 6 to pH 4 represents a hundredfold increase and a drop from pH 6 to pH 3 represents a thousandfold increase in acidity.

Remember: the lower the pH value, the higher the acid content. Each full pH unit drop represents a tenfold increase in acidity.

From: "Acid Rain"
U.S. Environmental Protection Agency
July 1980

SOME BACKGROUND: LOGARITHMS

Logarithms are exponents. Consider 2^4. The number 4 is called the exponent or power. The number 2 is called the base. The position of the number 4 is known as a superscript. 2^4 is shorthand for $2 \cdot 2 \cdot 2 \cdot 2$. It means 2 multiplied by itself 4 times or 16. 2^4 can also be read as 2 raised to the 4th power.

Some additional examples using exponents:

$2^6 = 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2 \cdot 2$ = _____

$3^4 = 3 \cdot 3 \cdot 3 \cdot 3$ = _____

$4^3 = 4 \cdot 4 \cdot 4$ = _____

$5^2 = 5 \cdot 5$ = 25

$6^7 = 6 \cdot 6 \cdot 6 \cdot 6 \cdot 6 \cdot 6 \cdot 6$ = _____

Powers of ten represent a special case of exponents. Consider 10^3 which is shorthand for: $10 \cdot 10 \cdot 10 = 1{,}000$. The exponent 3, tells how many times the 10 should be multiplied by itself. Just as in the example above, the number 3 is called the exponent or power and the number 10 is called the base.

Another way of looking at the exponent is as a way of telling how many places to shift a decimal point. For example, $1.0 \times 10^5 = 100{,}000$. The exponent is +5 and the decimal point shifts 5 places to the right. $1.0 \times 10^{-5} = 0.00001$. The exponent is -5 and the decimal point shifts 5 places to the left. so,

Logarithms are exponents. Logarithms with base 10, or common logarithms, are used in expressing the pH scale. The connection between logarithms and power of 10 is shown below.

10^0 = = 1

10^1 = = 10

10^2 = = _____

10^3 = = _____

10^4 = = _____

10^5 = = _____

10^6 = = _____

10^7 = = _____

a. $100 = 10^2$

b. $\log_{10} 100 = 2$

Equation b is read as follows: the logarithm (log, for short) of 100, to the base 10 is 2. The logarithm, 2 is the exponent or power to which 10 is raised. Equation b can also be written: log 100 = 2. In this case, the base 10 is understood.

The logarithm for 1,000,000 is written: $\log_{10}$ 1,000,000 = 6 or the logarithm (log, for short) of 1,000,000, to the base 10, is 6. The logarithm, 6, is the exponent or power to which 10 is raised to equal the number 1,000,000.

Therefore:

$\log_{10}$	1	=
$\log_{10}$	10	=
$\log_{10}$	100	=
$\log_{10}$	1,000	=
$\log_{10}$	10,000	=
$\log_{10}$	100,000	=
$\log_{10}$	1,000,000	=
$\log_{10}$	10,000,000	=
$\log_{10}$	1	=
$\log_{10}$	100	=
$\log_{10}$	1,000	=

GROUP MEMBERS: _____

_____

_____

THE pH SCALE: AN EXERCISE IN UNITS

SECTION I

The acidity of solutions is measured in pH units. The more acidic a solution is, the lower its pH reading. Examine the pH Scale and answer the following questions.

1. To what do the numbers refer?

2. According to the scale, how much more acidic is a solution of pH 3 than a solution of pH 7? pH 6? pH 5? pH 4?

3. A solution that has a pH _____ (less than, greater than) 7 is acidic.

4. Which is more acidic? (Circle one)

   a. pH 4.5 or 5.5?
   b. pH 3.2 or 3.1?
   c. pH 6.9 or 7.0?
   d. pH 5.6 or 5.3?

5. Does the pH Scale tell us anything about whether acids come from natural or human-made sources?

6. Place these solutions in the proper place on the pH Scale:

Solution	pH
Distilled water	7.0
Vinegar	2.2
Milk	6.6
Apples	3.0
Adirondack Mountain Lakes, 1930s	6.5
Lemon juice	2.0
Carrots	5.0
Tomatoes	4.2
"Pure" rain	5.6
Adirondack Mountain Lakes, 1975	4.8

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SECTION II

The pH scale is a logarithmic measure, that is, each decrease of one pH unit - say from 6 to 5 - represents a tenfold increase in acidity. Thus a drop from pH 6 to pH 4 represents a hundredfold increase and a drop from pH 6 to pH 3 represents a thousandfold increase in acidity.

From "Acid Rain." U.S. Environmental Protection Agency, July 1980

MATERIALS YOU WILL NEED

Ball of String/Thread/Yarn
Meter Stick/Metric Ruler
Masking Tape

GATHERING DATA

1. Secure one end of your string to the floor with a small piece (2-3 cm.) of masking tape.
2. As carefully as you can, measure 1 mm. from where the tape crosses the string and mark it with a pen or felt-tip marker. This is pH 7.
3. Use the string and meter stick to lay out a pH scale on the floor which accurately represents the true nature of the pH scale. You will find information in the quote above useful in making your measurements.
4. Record the interval data the data table. Give this table an appropriate name.
5. Use small pieces of masking tape (2-3 cm.) to indicate the location of the pH numbers.

Data Table.

pH	Interval Length - mm
7	
6	
5	
4	
3	
2	
1	

Section II (cont.)

Questions.

1. Locate the position of the solutions in Section I, Item 7. To help you do this, your teacher will place a transparency, "Interval Lengths and Acidity," on the overhead. Study it carefully while you are making your decisions.

2. On our scale the interval length from pH 5.0 to pH 5.6 is _____.

3. On our scale the interval length from pH 6.5 to pH 4.8 is _____.

4. Indicate how many times (10; 100; 1,000; 10,000; 100,000; 1,000,000; 10,000,000) each of the following changes in pH units represents.

   a. pH 6 to 5 _____

   b. pH 6 to 4 _____

   c. pH 6 to 3 _____

   d. pH 6 to 2 _____

   e. pH 6 to 1 _____

   f. pH 7 to 6 _____

   g. pH 7 to 3 _____

5. As acidity decreases, interval length (increases decreases). As acidity increases, interval length (increases decreases). For each pair, circle one.

6. The interval length of an acidic solution with a pH of 0 would be _____ mm.

7. Is there a relationship between pH and unit length? If so, what is it?

8. How much space would have been required if you had used centimeters?

9. What are some sources of error in this lesson?

INTERVAL LENGTHS AND ACIDITY

(NOTE UNITS)

Acidity Increasing	Interval Length (cm.)	Acidity Decreasing	Interval Length (cm.)
7.0	1.0	7.0	1
6.9	1.25	6.9	1.25
6.7	2		
6.6	2.5	6.6	2.5
		6.5	3.12
6.4	4		
6.3	5	6.3	5
		6.2	6.25
6.1	8		
6.0	10	6.0	10
		5.9	12.5
5.8	16		
5.7	20		
		5.6	25
5.5	32		
5.4	40		
		5.3	50
5.2	64		
5.1	80		
5.0	100	5.0	100

Physical Sciences

Consumer complaints: (pH)act or (pH)antasy?

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Overview

An article published in the New York Times, September 25, 1972, reported on an air quality study conducted by the New York State Environmental Conservation Department. According to the article, air quality in the Borough of Brooklyn, New York and North Pearl Street, Albany, New York, "is a prime enemy of nylon and can weaken the fabric substantially, making it more vulnerable to holes and runs." The air in those two places deteriorated nylon faster than anywhere else in New York State.

In this activity, students investigate the effects of artificial acid rain -- made from sulfuric acid -- on nylon.

Objectives

After completing this activity, students should be able to:

- describe specific effects of acids on a fabric, for example, concentration and time.
- discuss some experimental evidence about damage to materials by acidic deposition.
- discuss how representative a controlled laboratory investigation is of actual field conditions.

Materials

135 mm cardboard slide mounts (Used for fabric holders. Petri plates can be substituted.)
Nylon, good quality (15 denier) nylon hose. (Nylon may have to be purchased because nylon has been replaced by other hosiery materials.)
Masking tape
Scissors
Microscope slides
Dropping bottles
Stock acid solutions, sulphuric of pH 1, 2.5, 3.7, 4.2, and 6.4
Distilled water
pH indicator paper (narrow range) or pH meter
Hand lens
Laboratory safety goggles
Data Sheet, "Consumer Com(pH)laints"

Teacher Background

There is a considerable body of experimental evidence for damage to materials by acidic deposition. This includes all acidic pollutants, e.g., gases and solid and liquid particulate matter. Damage to materials from acidic deposition takes a variety of forms including the corrosion of metals, erosion and discoloration of paints, decay of building stone, and the weakening and fading of textiles.

All of these effects occur to a significant degree as a result of natural environmental conditions, even in unpolluted atmospheres. Moisture, atmospheric oxygen, carbon dioxide, sunlight, temperature fluctuations, and the action of microorganisms all contribute to the deterioration of materials. Quantifying the specific contributions of the air pollutants of an industrialized society to such change is a formidable research task. Furthermore, distinguishing the relative amount of damage caused by specific pollutant transformation and contact processes is a very elusive task.

The degradation of paper and textiles is dominated by three factors: light, humidity, and acidity. In textiles, such damage is best determined by measuring loss in tensile strength. Sulfur oxides are capable of causing deterioration to both natural and synthetic fibers.

Teacher Preparation

1. It is advisable to review laboratory safety rules and procedures whenever students start a new experiment. Do you have posters and signs that list laboratory rules? Are students familiar with the location of all permanent laboratory safety aids and do they know how to use them? There is one basic laboratory rule: When you work with chemicals, wear goggles.

2. Fabric choice. If you divide your class into groups, you can have students investigate the potential effects of acid precipitation on several different fabrics. This can lead to an interesting discussion of variables, fabric responses, and methods of measurement.

3. Acidic Solutions Recipe

pH 1	Add 5.5 mL of concentrated sulfuric acid to 94.5 mL of distilled water.
pH 2.5	Add 10 mL of pH 1 solution to 90 mL of distilled water.
pH 3.7	Add 10 mL of pH 2.5 solution to 90 mL of distilled water.
pH 4.2	Add 50 mL of pH 3.7 solution to 50 mL of distilled water.
pH 6.4	Add 10 mL of pH 3.7 solution to 90 mL of distilled water.
Control	Distilled water. Determine pH. If you would like it to be pH 7, you may have to boil it to eliminate CO_2.

You may want to label the stock solutions with symbols or letters (A, E, M, etc.) rather than with the known pH readings to reduce observer bias. If you do, be sure to keep a record of the pH the labels represent. Place the stock solutions in the dropping bottles.

Teacher Guidelines

1. Tell your students that the following paragraphs are from an article published in the New York Times, September 25, 1972.

   "The Borough of Brooklyn, and North Pearl Street in Albany are particularly hazardous places to wear nylon stockings, according to a report by the State Environmental Conservation Department.

   "The air in these two places deteriorated nylon faster than anywhere else in the state in recent tests, the department said. The air in the town of Petersburg in Rensselaer County (New York) deteriorated nylon stockings the least."

   Ask your students whether they think acid rain might be the cause. These questions will help guide the discussion:

   - What kind of evidence would convince you?
   - Where would you find such evidence?
   - Why would you believe the kind of evidence they suggest?
   - How could the effects of acid rain on fabric be studied in the laboratory?
   - What are some of the advantages and disadvantages of laboratory vs. field studies?

     Laboratory. The chief advantages are controlled conditions and specific effects can be studied. However, to produce measurable material damage in a reasonable time period, the material is often exposed to extremely high pollutant concentrations. The environmental factors are also different.

     Field studies. The major advantage is that the combination of pollutant concentrations and other environmental factors are representative. However, damage is a complex function of many environmental conditions, and the effect of one condition is difficult to isolate. The variables are often interrelated and it is difficult to know their relative importance in the outcome.

   This investigation is not as straightforward as it appears. It provides you an opportunity to discuss variables and how one of them is going to be measured. What do we mean by the term damage? These are some questions to help guide this discussion:

   - What is the responding variable in this problem? (The variable that changes as a result of manipulation.)
   - What are the variables that might affect the responding variable?
   - What is a hypothesis that relates a variable to the responding variable?
   - Which variable is to be manipulated in this investigation? (This is the variable that is deliberately changed in an experiment.)
   - What are the variables that need to be held constant in this investigation? (These are all the other variables the investigator can think of which might affect the experiment. The investigator tries to keep them the same while s/he manipulates one variable and observes the response of another.)
   - How is damage to the fabric to be measured? (Show me how you are going to measure discoloration or weakened fabric strength (loss in tensile strength) or fading or soiling or.... Students might decide to treat the fabric for a certain time period, then wash in a detergent, dry, and stretch the fabric to see whether it "runs.")

2. Divide the class into small groups and distribute copies of "Consumer Com(pH)laints." Make the connection between the opening discussion and the laboratory work. Review and clarify the assignment and note any changes in materials/procedures. Students should note these in the space provided.

   Also discuss with students how they will know when to stop the experiment. This depends on what they need to know.

3. When students have completed the work, have them report on the outcomes. One way to do this is to use a poster session. Each team presents their findings on a poster/poster-size sheet of paper. Each report should include four sections: a STATEMENT of the problem, PROCEDURES, OBSERVATIONS, (include tables), and an INTERPRETATION based on the observations. After the reports, discuss the work using these questions as a guide:

- Did everyone obtain the same results? What are some of the reasons for differences? Similarities?
- What does the primary effect of acid solutions on fabric(s) seem to be?
- In this experiment, how safe are you in assuming that acid precipitation accounts for damage to fabric? (Very sure, Sure, Not too sure, Unsure) What are some of your reasons?
- What is some additional evidence that would strengthen or weaken our findings?
- What are some things about acid rain that have not been investigated? How could we investigate these effects on fabrics?
- Can experiments like this prove a cause-effect relationship between exposure to acid rain and fabric change? Why or why not?
- What are some ways this experiment could be improved or changed to provide more information about fabric damage from acid solutions?

4. The work on which this activity is based may seem like a long time ago to students. They may wonder why there have not been more reports of such damage (The popular press does contain many articles ascribing damage effects to acidic deposition, but most of these are to soils or ecosystems or to masonry.). One reason may be replacement of nylon and the use of substitute fabric materials. Another might be control of certain acid-carrying particulate matter or a change in its distribution pattern.

   In the New York Times article, it was reported that the New York State of Environmental Conservation said "that acid soot in the air was a prime enemy of nylon and could weaken the fabric substantially, making it more vulnerable to runs and holes. The soot is composed of hot smoke particles, sulphuric acid, auto-exhaust pollutants and solvent vapors and droplets."

   For a more recent example of the potential for damaging effects from air pollution on materials, read and discuss the following excerpt from the 1982 Buick Owner's Manual:

NOTICE TO NEW BUICK OWNERS REGARDING CHEMICAL PAINT SPOTTING

Buick believes that certain weather and atmospheric conditions may create a chemical fallout whereby certain airborne pollutants fall upon and attack vehicle paints. Occurrences have taken place primarily in the northeastern seaboard area. The paint damage takes two forms: blotchy, ringlet-shaped discolorations, and small irregular dark spots etched into the the paint surface.

Paint spotting as a result of the fallout is not related to a defect in paint materials or workmanship. For this reason, claims arising from this condition are not considered to be warranty related. Nevertheless, because Buick shares the pride which our owners take in preserving and maintaining the appearance of their vehicles, Buick has authorized its dealers to repair, at no charge to the owner, the surfaces of new vehicles damaged by this fallout condition within 12 months or 12,000 miles (20,000 kilometers) of purchase, whichever comes first.

-- What is going on here? (Encourage students to report literally what this statement says.)
-- What does it mean? What are the possible interpretations?
-- Is this about acid precipitation? How sure are you?
-- How would you design an experiment to investigate this problem? (Assume that acid precipitation falling on the material surface could lead to damage directly.)

EXTENSIONS

1. In the laboratory, HNO_3 is often preferred to H_2SO_4 for oxidizing organic matter. Compare the effects of HNO_3 with H_2SO_4.

2. Examine the effects of the acid solutions on colored fabrics.

3. A wide range of sensitive materials can be changed by acidic deposition. Examine the effects of acid solutions of different pH on these material classes: metals, masonry, paint and other coatings, photographic materials, textiles (e.g., canvas, outer clothing material), and leather.

4. Investigate the effects of soot/particulates from a gas engine's exhaust, placed on fabrics and moistened with distilled water.

5. Examine the tensile properties of yarn exposed to acid solutions of varying pH.

Physical Sciences

No_xious oxides

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Name: _____

Class: _____

CONSUMER COM(pH)LAINTS

MATERIALS

135 mm cardboard slide mounts, 6
Fabric
Scissors
Microscope slides, 6
Masking tape
Dropping bottles
Hand lens
Tray

INSTRUCTIONS

1. Cut six pieces of fabric, each a little larger than the opening of the slide mount.
2. Stretch the fabric over the opening just enough to remove any wrinkles and tape it to the cardboard slide mount.
3. Label each cardboard slide mount according to the numbers/letters/symbols used on the dropping bottles.
4. Place 6 microscope slides in the tray. Set each fabric sample, label side up, on top of a microscope slide. This will catch any acid that might drip through.
5. Place 1 drop of the appropriate acid solution on each fabric sample you have mounted. (The label of the fabric sample should match the label of the solution.)
6. Observe the mounts for the next few days. Each time the drop dries up or disappears, place another at the same location.
7. Examine the cloth daily for any changes in the fabric samples and record them in your laboratory notebook.
8. Design a table for recording your observations. The table will need: a title, a listing of the solutions, and spaces to record the number of drops added, time (days), and space for observations.

9. Students are to observe and make notes as you perform the following demonstrations.

   a. Invert a bottle of the gas collected by air displacement and a bottle of the gas collected by water displacement into separate 1 L beakers of tap water with some universal indicator. This will demonstrate differences in acidity and solubility.

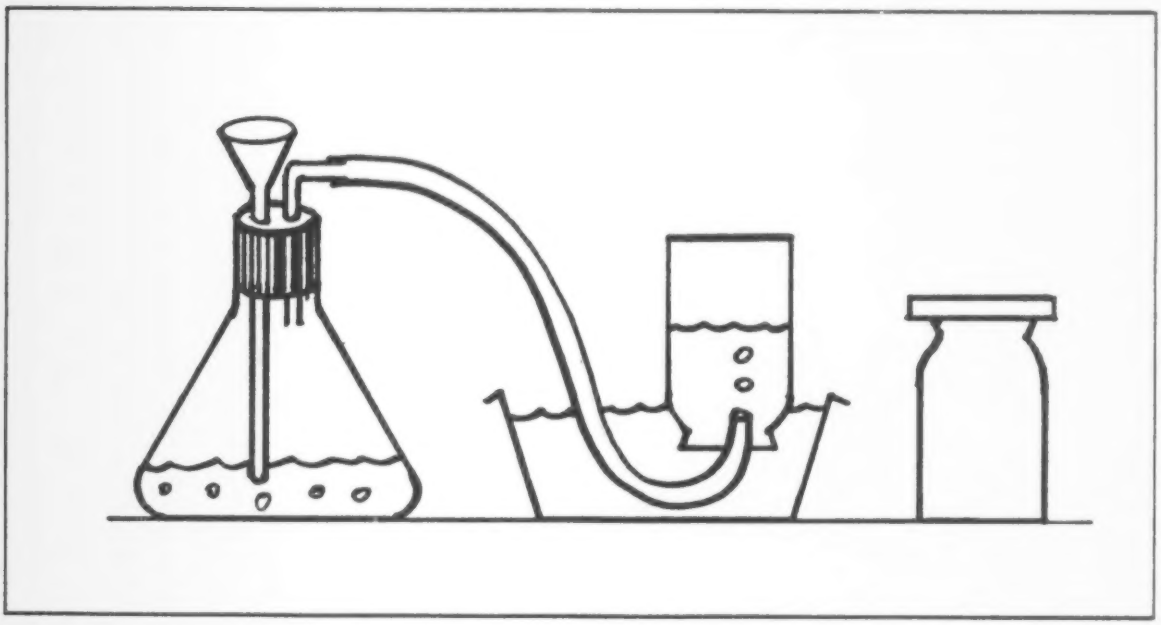
   b. Expose a bottle of the gas collected by air displacement to air.

   c. Add 2 mL of distilled water to the other bottle of gas collected by air displacement and shake it. (If you place the palm of your hand tightly over the top of the bottle it will cling to your hand.) Test the solution with litmus paper.

   d. Add 2 mL of distilled water to a bottle of gas collected by water displacement, recover, and shake it. Test the solution with litmus paper.

   e. Insert a glowing splint into the other bottle of gas collected by water displacement.

10. Review the chemistry of the work with the students. Use the data sheet and the demonstration as a basis for your summary of the work. The observations students made should allow you to discuss differences in acidity and solubility, the chemistry of color changes, rates of reaction, and gas properties. Then, explore some of the connections between the demonstration and acid rain.



NAME(s)_____

CLASS_____

NO_x IOUS OXIDES

1. Make a drawing of the apparatus and label it.

2. Carefully note all observations.

3. What are the similarities and differences between the gases collected by air displacement and by water displacement?

4. In this demonstration, what evidence is there of chemical change?

5. Write and balance the equations for all reactions in this demonstration.

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Name: _____

CONSUMER COM(pH)LAINTS

CHANGES IN MATERIALS/PROCEDURE

MEASUREMENT PROCEDURE TO DETERMINE DAMAGE

LENGTH OF EXPERIMENT

MATERIALS

DRAWING OF EXPERIMENT

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Overview

Students become familiar with the properties and characteristics of two oxides of nitrogen. The demonstration illustrates possible connections between emitted NO_x and acid rain.

Objectives

Through their experiences in this work, it is hoped that students will be able to:

- know that chemical changes produce new substances.
- identity one of the major sources of acid deposition.
- describe the chemical reactions associated with the transformation of NO_x in the atmosphere and in water.

Materials

Flask, Erlenmeyer, 50 mL
Rubber stopper, two holes
Glass tube, straight or angled
Funnel, long stem
Rubber/plastic tubing
Copper shot
4 widemouth gas bottles, 125 ml
Glass plates/Aluminum foil
2 beakers, 1L, 1 beaker, 100 mL
Cylinder, graduated, 10 mL
Pan, plastic or metal
Balance
Indicator paper, blue and red
Universal indicator
HNO_3, concentrated
Data Sheet, NO_xious Oxides
Distilled water

Teacher background

Nitric oxide (NO) is the most commonly emitted oxide of nitrogen. Less than 10 percent of nitrogen oxides are emitted as nitrogen dioxide (NO_2). Exceptions are found in emissions from some types of diesel and jet turbine engines and gas from citric acid plants, which can contain from 30 to 50 percent nitrogen dioxide. Because nitric oxide converts rapidly to NO_2 in the atmosphere, NO_2 is the predominant form of nitrogen found outside cities. Subsequent atmospheric reactions result in the formation of nitric acid. Listed below are some of the major conclusions based on current measurement results and analysis of issues.

- Nitrogen oxides reach about the same concentration range as sulfur dioxide in cities. Their concentrations have become more significant relative to sulfur dioxide with the decrease in sulfur dioxide emissions. The contribution of nitrogen oxide to atmospheric acidity is increasing in both eastern North American an western Europe.
- Nitrogen oxides are substantially lower in concentration in rural areas than in urban areas.
- Nitrogen dioxide concentrations are substantially lower in rural areas within the western United States than in the eastern United States.
- Emitted NO_x is extensively involved in complex atmospheric chemical reactions. The chemical processess make an accounting of the pathways and fates of emitted NO_x a more complex matter than is the case for SO_2.
- NO_x emissions are expected to rise more sharply than SO_2 emissions over the balance of this century. In the eastern United State the two largest sources of anthropogenic NO_x emissions in 1980 were the transportation sector (44 percent) and the utility sector (34 percent). The projections for the year 2000 still show these two sectors dominating NO_x emissions, but the relative shares should be about equal. In 1980, coal

burning accounted for 78 percent of national utility NO_x emissions, and this share is likely to increase as coal continues to play a larger role in electricity generation.

- More effective NO_x control technologies for utility emissions are expected to become commercially available within the next decade. NO_x emissions from diesel-powered trucks have increased more than 150 percent since 1970. This growth in truck NO_x emissions, however, is likely to be balanced, at least in this decade, by a downward trend in passenger car NO_x emissions which can be expected to continue through the 1980s under present policy. This is because the auto fleet, which takes over a decade to turn over, is in the process of being replaced by cars conforming to the lowered NO_x emission limit--one gram per mile of travel--that only went into effect in 1981.

Teacher preparation

1. Use this lab to teach and reinforce laboratory safety procedures. The science teacher has to provide the example. You and all of your students should wear safety goggles. It is a law in some states. You may also want to wear a lab coat or lab apron. Discuss what to do in the event of an acid splash--flush--and/or spill--absorb, isolate and immediately remove the spill chemical for disposal. Make sure that baking soda is available for use on any acid spills.
2. When generating toxic gases such as oxides of nitrogen you should make only very small quantities and use the hood. The hood should be free of all other chemicals. There are many reasons not to use a hood for chemical storage. The room should be well ventilated.
3. Do not use copper turnings; the reaction occurs too quickly.

Teacher guidelines

1. Distribute copies of the "NO_xious Oxides" data sheet to your students and review it with them. Remind them to make good use of their observing eyes. There is a lot going on and to keep track of. Explain the apparatus before you start.
2. Arrange the apparatus as shown in the drawing below. Have four bottles filled with water and four glass plates/pieces of aluminum foil ready so that the gas can be collected by water displacement.
3. Remove the stopper and place 3 grams of copper shot into the flask.
4. Replace the stopper and add 5mL of water through the funnel. Be sure that the stem end of the funnel tube is below the water level. It should not touch the bottom of the flask.
5. Place two filled bottles of water into the pan in preparation for collecting the gas.
6. Add 4 mL of concentrated HNO_3 through the funnel tube and collect two bottles of gas by air displacement. Cover the bottles with glass plates or aluminum foil.
7. Then, collect two bottles of gas by water displacement. Cover the bottles with glass plates or aluminum foil. If the generator will not produce four bottles of gas, add 2 mL of concentrated HNO_3.
8. When you have completed collecting the gas, stop the generator action by slowly pouring water through the funnel tube into the flask.

Physical Sciences

Representative sam(pH)les

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Overview

Sampling is the first of a series of steps leading to the generation of water-quality data. It is an exceedingly important one. Care must always be taken to ensure obtaining a sample that is truly representative. Further, the integrity of the sample must be maintained from the time of collection to the time of analysis. If the sample is not representative of the system sampled or if the sample has changed in chemical composition between the time of sampling and analysis, an accurate analysis of water quality will not be possible.

In this activity, students learn some considerations in obtaining: 1) a representative sample, 2) a clean sample, free from contamination, and 3) a sample that minimizes handling and exposure to potential sources of external contamination. The emphasis is on pH and, to a lesser extent, alkalinity measurements. This activity is to be used before you go into the field to collect samples.

Objectives

Students will be able to:

- o define a representative sample.
- o recognize the importance and influence of lake basin characteristics on water sampling procedures.
- o distinguish sampling sites and procedures which are relevant to the solution of a problem from those which are not.
- o disucss reasons for conscientious quality control in the collection of water samples.
- o recognize devices used for collecting water samples and know which ones to use for particular situations.

Materials

Student Data Sheets-
Sam(pH)ling I: Reading
Sam(pH)ling II: Lakes and Streams

Teacher Data Sheet-
Sam(pH)ling I: Answers for Lakes and Streams

Information Sheets-
Sam(pH)ling Devices
Sam(pH)les

Teacher guidelines

1. Begin this activity by having students read "Sam(pH)ling I: Reading". After completion of the reading, a discussion should follow. These questions will help guide the discussion.
   - o What are the main ideas in this reading? (List these on the board. After the main ideas are listed ask students to identify supporting details. List them after the main ideas.)
   - o How would you define epilimnion, metalimnion, and hypolimnion?
   - o In the graph, at about what level does a rapid drop in temperature first occur? At about what level does the temperature become uniform again? What is the name of the layer limited by these two boundaries?
   - o How do you think this remarkable distribution of heat in a lake becomes a uniform temperature again?
   - o Put the words "warmer" and "colder" on the blackboard. How would you describe what direction the thermocline goes in the summer? Would this be true for a lake in the winter? What is your explanation?
2. Now, give students a copy of "Sam(pH)ling II: Lakes and Streams". When students have completed the work, review and discuss their answers with them. Make sure that students understand that there are many decisions that must be made before an investigator ever collects a sample in the field.

Students should also be reminded that the vulnerability of a lake to the effects of rainfall acidity is a complex interplay of hydrology, geology, soil composition, vegetation type and climatic factors. Lake water pH can be influenced significantly by the depth to which precipitation seeps into the soil before flowing laterally into the lake. Bedrock characteristics also play a role. Limestone bedrock can give the soil in a watershed an edge in neutralizing rainfall acidity; granite bedrock decrease the watershed's ability to neutralize acidity. The slopes of a watershed can also have an influence. A steep incline around a lake increases the probability that acidic rainwater will flow directly into the lake rather than through neutralizing soil.

3. Before you go into the field, review the information sheets on sampling devices and sample storage with the students. If you have some students who are interested, have them make some "stick samplers" for use in class field work and for special projects.

Sam(pH)ling I: Reading

Sampling is the first of a series of important steps leading to the development of data about water quality. Care must be taken to ensure that water samples are truly representative of the body of water sampled. Sampling is the process of collecting a representative portion of the environment to learn about the rest of the environment.

A representative sample is one that resembles almost all possible water samples you could collect at a site in some way. The goal is to collect a sample which resembles actual conditions within a lake. The sample is one as free as possible from contamination, e.g., bottom sediments, surrounding vegetation, water traffic, etc.

If a region is typified by a certain type of land use, the sampling site should reflect this usage. A good lake or topographic map is very helpful in determing sampling sites. The ideal map should show shoreline development (houses, etc.), land-use within the lake's watershed (urban, agriculture, forest, highways, bogs, etc.), streams flowing in and out of the lake, and bottom contours.

The physical characteristics of the water body are also involved in the proper selection of surface-water sampling sites. In selecting sampling sites, it is best to pick spots that are not heavily influenced by possible sources of chemical influence. Temperature (which is a function of solar radiation) is the main factor that affects variations in water chemistry. As you read the following, compare the explanation with the accompanying illustrations.

In most northern states, many lakes are frozen in the winter. The water beneath the ice is generally of uniform temperature and chemistry. There can be some differences in temperature from top to bottom but they are generally smaller than summer differences. Usually, in Spring, after the ice is out, winds mix the water of a lake, resulting in a uniform temperature and chemistry. Sampling performed in the Spring, within a few weeks after the ice is out, usually provides a "well-mixed" representative sample of the lake. Snowmelt can, however, change lake (and stream) water in the Spring and result in chemical values different from annual averages.

In the summer, thermal and chemical stratification occurs in most lakes although it depends on the morphology of the lake. (Very shallow lakes are not likely to stratify.) In thermally stratified lakes, the upper layers of the lake are warmer than the bottom layers. The bottom layer, the hypolimnion, is cooler than the surface layer, the epilimnion, and an intermediate layer, the metalimnion, forms a boundary between the two. It is a layer of thermal discontinuity.

The metalimnion or thermocline is the place between the epilimnion and the hypolimnion. It is defined by a drop in temperature of 1.0° C for every depth increase of 1.0 meters. The chemistry of the lake is often different within these three layers and these differences should be accounted for in a good, complete survey of a lake.

In the fall the average lake undergoes fall turnover. As a result of this mixing, fall is a good time for sampling. It may be the best time of year to sample. A lake can be sampled at any time of the year. However, if only surface or near shore samples are to be taken, sampling after spring turnover or after fall turnover will provide a representative sample of the lake. In summer, it's best to take surface and depth samples.

NAME(s)_____

CLASS_____

Sam(pH)ling II: Lakes and Streams

STUBBS POND

Bog

Intermittent
Flow
(Spring Snowmelt/
Heavy Rain)

1. Identify inlets/outlets.

2. You have personnel, equipment and money for four possible water sampling sites on this lake. Indicate where you would take them and, for each choice, your reasons. Assume that it is Fall.

3. Indicate four sites where you would not take samples and explain your reasons.

4. If you were limited to the shoreline and could take only two samples from this lake, where would you take them? Why? If you could take only one shoreline sample, where would you take it? Why?

5. If you had to choose one place, what is the "best" sampling spot? In Summer? Winter? Why?

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Stream Sampling

Streams in Minnesota usually experience peak flow during and shortly after snowmelt. Fall rains tend to swell stream flow as well. Streams water quality can vary considerably with stream flow because stream flow increases the amount of suspended materials and materials washed from agricultural lands, roads, etc. A sample from the middle of the stream, away from "point sources" of inflow such as storm drains is best for stream sampling. The ideal sampling site for a stream is a cross section that would give the same sample at all points across the stream and at all sampling times.

a. Make an advantages/disadvantages chart for the seasons - spring, summer, fall, and winter. To completely characterize the water chemistry of the stream, when should you sample a stream?

b. What is an advantage of collecting a water sample from a bridge? What is a disadvantage?

c. From which side of a bridge would it be best to take a sample? Does it make any difference? Explain your reasoning.

d. How might summer and late winter-early spring stream pH differ from one another? Explain your reasoning.

e. Does the situation described in the last sentence ever exist in nature? Why? What does such a statement tell you about site selection?

Sam(pH)ling I: Answers for Lakes and Streams

STUBBS POND

Sam(pH)ling I: Answers for Lakes and Stream

Site (1). A good (the best) spot if a boat is available or for winter. Generally, the center of the lake and near or over the "deep hole". Likely to give the most representative lake sample. Also a good spot if depth samples are to be taken.

(2). Sampling the streams that feed the lake will give a good identification of their contribution to lake chemistry. This is especially good if more than one stream feeds the lake (3) and is good to demonstrate the influence of different land-uses around the streams.

(4). Sampling near the outlet is generally good for a representative lake sample if a boat is not available (it integrates the lake). The outlet is good for the complete documentation of the lake. Caution is urged if the outlet is near inlets because the water flow can short circuit the body of the lake.

(5). If possible, it is best to avoid sampling near homes or cabins. However, if a dock sample is all that can be collected, pick a dock on the main open area of the lake if possible. Yard runoff, road, septic tanks, boat oil, etc., can affect the "representativeness" of the sample. The investigator must know the potential sources of contamination from housing complexes, agricultural areas, etc., to select sampling sites that will yield the data needed to meet project objectives.

(6)(7). Avoid sampling small bays and especially the docks from houses in small bays. Water in a bay may not mix fully with the rest of the lake. However, such samples should be taken if an intensive sample program is planned.

(8). Again, unless intesive sampling is planned, try to avoid sampling near bogs or marshes. Rocky, sandy shores are best for shore-line samples.

INFORMATION SHEET: Sam(pH)ling Devices

Most sampling devices are made from plastic or a similar substance. Plastic is desirable because it will not interact significantly with the sample. Breakage is a major concern with glass. Most metals are potentially "reactive" and may contaminate the sample.

All sampling devices and containers should be washed carefully with soap and water and rinsed before they are used in the field. The sampling device should be rinsed at least three times with distilled-deionized water or distilled water. Tap water is all right if you are interested only in pH and alkalinity measurements.

For some of the techniques, especially where collecting bottles/containers are to be re-used, the samplers can be rinsed with lake or stream water near subsequent sampling locations. Each sampling device should be rinsed a couple of times. The sampling device does not have to be completely filled with water to ensure a thorough rinsing.

TECHNIQUES

1. "Wet Arm Technique"

   This is not a good winter technique.
   a. Roll up sleeve.
   b. Dip a plastic jug or bottle into the water to a depth half way between your elbow and shoulder.
   c. Unscrew the top and allow the container to fill. (Hold nearly upright)
   d. Replace the cap.
   e. Transfer the sample to separate storage containers if necessary.

2. Bucket and Rope
   Lower a bucket from a bridge to sample streams and rivers.

3. Stick Samplers
   a. If necessary, place bottle or jug in a hose clamp and tighten to secure jug.
   b. Reach away from the dock, boat, or shore and dip into water to a depth of 1 m (2-3 feet).
   c. Draw the device out of the water. Make sure you hold the bottle/jug upright.
   d. Either remove the bottle and cap it, or carefully pour the sample into storage bottles.

4. "Bomb" samplers
   Usually purchased from a scientific supply company. They can be constructed in a good shop.
   a. Place clean bottle into canister.
   b. Insert the filling tube/lid assembly into the bottle and screw the cap down.
   c. Lower the sampler into the water to the desired depth rapidly (marking the rope is helpful). Hold long enough to allow complete filling. You should both practice and time this.
   d. Withdraw the sampler. Remove the lid/filling tube assembly and cap the bottle.

5. Depth Samplers
   This is the best method for "deep" samples, especially in very deep lakes, e.g., more than 15 meters). The device must be purchased. It allows collection of good, representative samples in deep bodies of water.
   a. The top and bottom are cocked and a marked line is attached.
   b. The sampler is lowered to desired depth. A lead weight, called a messenger, is attached to the line and allowed to drop along the line to trip the lid and bottom, sealing the water from that depth inside.
   c. The sampler is withdrawn from the lake.
   d. The sample is removed via the drain.

INFORMATION SHEET: Sam(pH)les

Samples

1. **Containers**
   Thoroughly cleaned plastic (or glass) bottles fitted with screw caps may be used for water samples. Plastic containers are generally preferred for inorganic samples.

2. **Bottle washing**
   All containers (anything that touches the sample) should be thoroughly washed with soap, water and a bottle brush. The sampler and the storage bottles should be rinsed 3-5 times with clean water. A little water rinses just as well as a bottle full. Distilled-deionized water is best for rinsing although plain distilled water is acceptable. Tap water is all right if alkalinity and pH are the only measurements you are interested in.

3. **Storage**
   For pH, alkalinity, and the most routine chemical determinations, pack samples in ice in the field and place them in a refrigerator when you return to the lab. pH and alkalinity should be measured as soon as possible; within 24 hours at least. Deteriorated samples negate all the efforts and costs expended in obtaining good samples. Allow samples to warm to room temperature before analysis.

4. **Sample identification**
   Identify the samples with detailed and accurate descriptions. Record every sample collected. Identify every bottle, preferably by attaching an appropriately inscribed top or label. The name of the person collecting the sample should also be recorded.

5. **Quality Control - Replicates**
   It is always a good idea to collect more than one sample from each sampling site.

6. **Personnel**
   Observant and conscientious field personnel are essential to any monitoring study.

Rain(pH)all

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Overview

Student learn how to take pH measurements of liquid precipitation under field conditions. Information is provided on how to develop a packet of materials which can be easily carried into wilderness areas or on overnight camping expeditions or used in local environments.

Objectives

Through their experiences in this work, it is hoped that students will:

- o recognize the need to acquire new skills.
- o develop a willingness to examine evidence critically.
- o improve their ability to use scientific equipment for extending the range of human senses.
- o recognize some of the human impacts on the environment.
- o become aware that the degree of accuracy of measurements has to be taken into account when results are interpreted.
- o gain knowledge of the variation in acid rain episodes.

Materials

The materials are described in terms of a packet that a person/small group can carry into a wilderness area. Each packet contains sufficient materials for determining the pH from at least five rain producing weather systems.

Quantity	Item	Notes
1	Rain(pH)all Instruction Sheet	Plastic laminated
5	Rain(pH)all Data Sheets	Data sheets for 5 rain storms, 2-sided
1	Pencil	Greenhouse type
2	Thermometers	Pocket type, student thermometer, single or double scale
1	Plastic Tarp	Heavy duty, 1 m^2
1	Graduated Cylinder	500 mL, plastic
1	Rain Gauge, wedge	Plastic, measures up to 15 cm. of rain
10+	pH Sticks, Wide Range	Permanent type, ColorpHast ^{R}
18+	pH Sticks, Narrow Range	Permanent type, ColorpHast ^{R}
1	Storage Bag/Vial	To store used, dry pH papers (Color is permanent)
1	Case	Plastic, waterproof
1	pH Colorchart, Wide Range	Plastic laminated
1	pH Colorchart, Narrow Range	Plastic laminated
1	Map	Expedition area
1	Map	Acidity of Wet Deposition, North America, 1982. (Overhead transparency, plastic laminated if taken into field)
1	Map	Areas Sensitive to Acid Deposition, North America
1	Rain(pH)all Summary Sheet	Worksheet for discussing and summarizing the work. One for each group/student.

Teacher Preparation

1. Weather. Weather is sometimes described as everyone's favorite subject although atmospheric events remain a mystery to many of us. The more familiarity students have with the identification and explanation of clouds and storms the better.

2. A note on map coordinates. Use latitude or longitude or have students arbitrarily mark off a map with X and Y coordinates. Use a metric ruler. The millimeter scale should be sufficient: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130...210, 220, 230, 240...n. A sample location could read: X:09; Y:235 or X09; Y235 or X-09; Y-235. You could also use the system found on road maps: H-9, A-14.

3. Students can also investigate their immediate surroundings for evidence of acid rain. You will probably have to make minor modifications in the field kit. Select 3-4 locations for sampling rain around the school or in the community: open fields, wooded/bushy areas. Each location should be different. Each team should take one measurement. This will allow you to take several measurements at each location. You can obtain a neighborhood/community pH profile by assigning this activity as an overnight assignment. Students can take pH measurements at home.

Teacher Guidelines

1. Provide students the science background and the societal implications of acid rain.

2. Divide your class into small work teams. Distribute and review the "Rain(pH)all Instruction Sheet" and the "Rain(pH)all Data Sheet" (Two sides). Carefully go over the instructions on establishing a sample collection station with the class.

3. Select the sample collection stations and remind students of any safety precautions, e.g., lightning, hazards associated with locations, etc. Determine when you are going to collect the rain, e.g., when it stops raining or in the morning.

4. Have students make measurements and record the data.

5. When the groups have completed their research, each group should report its findings to the rest of the class. After each group has presented the results of its research, the class should try to reach some conclusions based on the following kinds of questions:

- How does pH compare from one location to another?
- How does the pH compare from one acid precipitation episode to another? What is the range? What is the average pH?
- What was the lowest pH? The highest? What might be some reasons for these differences? Did any team attempt to capture the flow of rain from the stem/trunk of a tree? How does it compare with direct deposition or the rainfall directly under leaves/needles? With rain collected in an open area?
- Do you have any evidence that the pH varied during the duration of the rain episode? Was it higher at the beginning of the rain episode than it was at the end of the rain episode? How do you account for any observed differences?
- What is the reason for repeating the narrow range pH measurements several times?
- What was the average pH? How does this compare with the range?
- How do the pH data we collected compare with that of a healthy atmosphere?
- Place the maps, "Acidity of Wet Deposition, North America, 1982" and "Regions Sensitive to Acid Deposition, North America" on an overhead projector and distribute the "Rain(pH)all Summary Sheet" to each student/team.

RAIN(pH)ALL INSTRUCTION SHEET

All data are to be recorded on the Data Sheet in greenhouse type pencil.

I. SAMPLE COLLECTION

A. Before or at the first hint of rain, spread the 1 m^2 plastic tarp on the ground, in an open area, away from trees. Anchor it.
B. Position the rain collecting graduate so that it catches rainwater run-off from the tarp. This will require some ingenuity and you may have to rearrange your anchors. Keep tarp clean.
C. Place the rain gauge in the same general area as the tarp.
D. At intervals throughout the rainstorm, collect water samples and record the sample data described in Part III.

II. GENERAL

A. Side I - Rain(pH)all Data Sheet
   1. Record name (address if on wilderness trip/neighborhood); group number and names.
   2. Date sample taken.
   3. Describe the rain sample site: location and vegetation. Provide as much detail as you can.
   4. Actual location: record map coordinates or attach a map to the data sheet with the sample site location clearly marked.
   5. Note the duration of rainfall. Time Began, Time Stopped, and Total Time of Precipitation.
   6. Describe the cloud type if you can or sky conditions: completely overcast, thunderheads, passing showers, etc., or use a word description of your own. You can check it against a weather guide when you return home.

III. SAMPLE DATA

If it rains long enough, attempt to collect at least three samples during the rainstorm's duration. Record the following data for <u>each</u> sample:

A. Side II - Rain(pH)all Data Sheet
   1. Time sample taken.
   2. Rain intensity - i.e., downpour, light, medium, heavy, mist, etc.
   3. Wind direction.
   4. Wind speed (best estimate). (Beaufort scale)
   5. Air temperature.
   6. Amount of rainfall accumulated <u>per</u> sample (Rain Gauge).
   7. Determine the pH. Use the wide range pH paper which gives the pH to within one pH unit (Record). Obtain a more accurate pH reading by using the appropriate narrow range pH paper. Take three readings and record them on the Data Sheet.
   8. Determine the overall pH of the entire rainfall by testing the rainwater collected in the rain gauge during the rain. Record.
   9. Record total accumulation (Rain Gauge).
   10. Dry the used pH papers, label them with the sample number, and place them in the used pH storage vial. Do <u>not</u> discard used pH papers wet or dry on site. Pack them out.

IV. Check the local pH index, if one is available for the area.

Name: _____

Group Number: _____

Group Members: _____

_____

Address: _____

_____ Zip _____

RAIN(pH)ALL DATA SHEET

(SIDE ONE)

I. Instructions:

Complete this Data Sheet by following the directions on the Instruction Card enclosed in this packet.

II. General Data

1. Date Sample Taken _____

2. Site Description _____

_____

_____

3. **Map Location:**

Coordinates _____
(Or attach map with location marked)

4. **Rainfall Duration:**

Time Rain Began _____

Time Rain Stopped _____

Total Time of Precipitation _____

5. Cloud Description/Sky Conditions _____

_____

6. pH of Total Accumulation _____

7. Total Rain Accumulation (run-off) _____ $cm.^3$ or $mm.^3$.

8. Total Rainfall (measured in rain gauge) _____ $cm.^3$ or $mm.^3$.

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RAIN(pH)ALL DATA SHEET

(SIDE TWO)

III. Sample Data

Sample #	1	2	3	4	5
1. Time Sample Taken					
2. Rain Intensity					
3. Wind Direction					
4. Wind Speed					
5. Air Temperature					
6. Sample Accumulation					
7. pH of Sample					
a. Wide Range					
b. Narrow Range					
Trial 1					
Trial 2					
Trial 3					
8. Local pH Index (if available)					

ACIDITY OF WET DEPOSITION, NORTH AMERICA, 1982

MAP

SOURCE: Interagency Task Force on Acid Precipitation, Annual Report, 1983, to the President and Congress, Washington D.C., June 1984, p. 36.

REGIONS SENSITIVE TO ACID DEPOSITION, NORTH AMERICA

SOURCE: Interagency Task Force on Acid Precipitation, Annual Report, 1983, to the President and Congress, Washington D.C., June 1984, p. 36.

Name: _____

RAIN(pH)ALL SUMMARY SHEET

Your teacher will show you two maps. Use them to answer the following questions.

1. Which parts of North America receive acid rain? _____

2. Which parts of North America are susceptible to the effects of acid rain?

3. Based on what you know about acid rain, geography, geology, soils and vegetation of North America, what are some reasons regions might differ from one another in terms of their susceptibility to the effects of acid rain? _____

4. What can you say about the pH of acid rain where you live? _____

5. What can say about the susceptibility of your region to the effects of acid rain? _____

6. What do you notice about acid rain and regions of North America susceptible to its effects?

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Physical Sciences

Snow(pH)all

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Overview

Students learn how to test the pH of snow under field conditions. The activity is designed to be used: (1) by students backpacking on skis or snowshoes for several days or more in wilderness areas, where laboratory equipment is not readily available or practical; and (2) by students right outside their classrooms or in their neighborhoods.

Objectives

Through their experiences in this work, it is hoped that students will:

- o increase their awareness of changes in the physical environment brought about by human activities.
- o gain knowledge of specific chemical tests.
- o gain practice in handling equipment, taking measurements and recording data.
- o become aware that the degree of accuracy of measurements has to be taken into account when results are interpreted.
- o gain knowledge of ways to investigate and measure properties of non-living materials.
- o appreciate and understand the need for careful measurements.

Materials

The materials are described in terms of a packet that a person/small group can carry into a wilderness area on a cross-country ski or snowshoe trip. Each packet contains sufficient materials for sampling snow pH from ten locations.

Quantity	Item	Notes
1	Snow(pH)all Instruction Sheet	Plastic card laminated
1	Snow(pH)all Data Sheet	Appropriate for 10 snow samples
1	Pencil	Greenhouse type
1	Thermometer	Pocket type, student thermometer, single or double scale
1	Collecting Card	Stiff plastic, 10 cm. x 10 cm.
1	Collecting Tube	Plastic drain pipe, 1 meter long, 2-inch (5 cm.) diameter
20	Storage Bags for Ten Samples	Heavy duty plastic, Ziploc bags of equal size. Each bag should have a small square of masking tape attached to it.
10+	pH Sticks, Wide Range	Permanent type, 1 per sample, ColorpHast®
30+	pH Sticks, Narrow Range	Permanent type, 3 per sample, ColorpHast®
2	Plastic Vials	To store used, dry pH papers (Color is permanent)
2	pH Color Charts	Plastic laminated
1	Graduated Cylinder	Plastic, 25 mL
1	Packet Case	Heavy duty Ziploc bag
1	Map	Expedition area
1	(pH)ailing Snow	Worksheet for discussing and summarizing work. One for each group/student.

Teacher Preparation

1. Each team of 2-4 students can construct a tool for measuring snow depth. They will need a 1 meter length of 2-inch (5 cm.) plastic drain pipe. Students can bevel the edge of the pipe at the bottom end, mark off 2.5 cm. intervals starting from the bottom, and drill 3/16-inch (about 4.5 mm.) holes at each mark for viewing the interior. Numbers can be painted -- a permanent marker works well -- on the plastic pipe.

2. A note on map coordinates. Use latitude or longitude or have students arbitrarily mark off a map with X and Y coordinates. Use a metric ruler. The millimeter scale should be sufficient: 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130...210, 220, 230, 240...n. A sample location could read: X:09; Y:235 or X09; Y235 or X-09; Y-235. You could also use the system found on road maps: H-9, A-14.

3. Students can also investigate their immediate surroundings for evidence of acid deposition. You will probably have to make minor modifications in the field kit. Select 3-4 locations for snow sampling: open field, wooded/bushy areas, etc. The locations should be different and you may substitute for them. Each team should take one measurement at each of the locations chosen. This will allow you to take several measurements at each location. You can obtain a neighborhood/community profile by making this activity an overnight assignment. Students can take pH measurements at home or bring the snow collection bags back to the classroom and complete the lab analysis there. One teacher had students collect four snow samples from home (old snow/fresh snow/near traffic/away from traffic) and compare them with four similar samples collected from the school grounds.

Teacher Guidelines

1. Provide students the science background of acid deposition and implications for society.

   Acidification of lakes and streams during snowmelt or heavy storms, apparently as a result of acidic deposition, has been demonstrated in Norway, Sweden, Finland, Ontario, and the northeastern United States. One hydrologic event that may lead to short-term acidification is snowmelt; however, periods of heavy rain can also result in short-term decreases in alkalinity and pH.

   Fish kills apparently associated with acid episodes have been reported in some streams and rivers of Southern Norway. Fish kills attributed to short-term acidification have been reported for only one body of water outside of Norway. During each spring from 1978 to 1981, coincident with spring run-off, dead and dying fish, especially pumpkinseed sunfish, were observed in Plastic Lake, LaCloche Mountain Region, Ontario, Canada. Negative effects on fish may not be the result of acidity <u>per se</u>, but due to the release of toxic elements (i.e., Al, Pb,) into waters with low pH.

   In addition to these observations of mass mortalities of fish attributed to acid episodes under natural field conditions, several instances of unusually heavy fish mortality have been reported within fish hatcheries receiving water directly from lakes or rivers. In Norway, poor survival of eggs and newly-hatched larvae of Atlantic salmon, attributed to water acidity, were reported as early as 1926. In Nova Scotia, 19 to 38 percent mortality of Atlantic salmon fry occurred in 1975 to 1978 at one hatchery. In the Adirondack Mountains, adult, yearling, and larval brook trout, which had been maintained without incident over the winter 1976-77 in water from Little Moose Lake, experienced distress and mortality during the first major winter thaw in early March. Deaths included three adult brook trout, 25 yearlings, and an undetermined number of recently hatched fry.

2. Divide your class into small work teams. Distribute and review "Snow(pH)all Instruction Sheet" and "Snow(pH)all Data Sheet" (two sides). Be sure students understand the sequence of steps.

3. Select the sample collection sites, collect the snow samples, and record appropriate data.

4. At base camp or back in the classroom, the snow can be melted. The water from each bag can be poured into a graduated cylinder to measure the volume of water. Students should make the pH test first and then pour the contents into the graduated cylinder so there is no contamination from one sample to another.

You may want students to convert the water volume measured in milliliters to its water equivalent: the depth of water that would result from the melting of a snow cover or snow sample. According to Snow Depth and Snow Melt (U.S. Fish and Wildlife Service Outdoor Classroom Environmental Education Guide Number 6), "one inch within a tube having a 1.55-inch diameter would equal a volume of 1.89 cubic inches or 30.9 (31) milliliters $\pi r^2 h$. So the depth of melted snow-water would equal its volume in cubic inches divided by 1.89, or its volume in milliliters divided by 30.9 (one fluid ounce = 1.8 cubic inches = 29.6 milliliters). Each team can then record each water volume measured in inches on its data sheet." If your plastic pipe has a different diameter, use the formula for the volume of a cylinder: $\pi r^2 h$, where r = the radius of the cylinder and h = the altitude.

5. When the groups have completed their research, each group should report its findings to the rest of the class. After each group has presented the results of its research, the class should try to reach some conclusions based on the following kinds of questions:

   - Where is the snow depth least? Most?
   - In what ways can the wind affect snow depth? The sun? What other factors can affect snow depth?
   - What is the lowest pH? The highest? What might be some reasons for these differences?
   - What was the purpose of gathering descriptive data from the sample site?
   - Why did we test the pH of each sample several times?
   - Can any of our data be used to find out whether there is a difference in pH between a "dirty" snow column and a "clean" one?
   - What can you say about the chemical make-up of snow from your observations?
   - What conclusions can you draw from the data?
   - Would you say you have sufficient data? Why or why not?
   - If you were going to repeat this investigation, how would you improve it?
   - How would you design an experiment to find out whether there were geographic differences in the pH of snow in Minnesota?
   - Where would you expect snow to be more acid? In a city or in a remote wilderness? Why? How would you go about finding out?
   - How could you find out whether the "age" of a column of snow made a difference in the pH of the snow?

6. Give students a copy of "(pH)alling Snow." Use it as a basis for class discussion.

SNOW(pH)ALL INSTRUCTION SHEET

All data are to be recorded on the data sheet in permanent ink.

I. DESCRIPTIVE DATA

Before Sample is Collected

A. SIDE ONE - DATA SHEET: SNOW pH

1. Record Name (address if on wilderness trip); and Group Number and Names.
2. Site Description
   a. Surrounding vegetation, geologic formations and location: snow on river ice, on lake ice, on trail or logging road, in a bog, etc. Be as specific as possible.
3. Sky Description
   a. % cloud cover, cloud type, whether it's snowing, etc.

B. SIDE TWO - DATA SHEET: SNOW pH

1. Date
2. Time
3. Snow type (i.e., old, recently fallen, or new fallen snow)
4. Air temperature
5. Wind direction (estimate wind speed)
6. Snowfall duration (time began and time ended if known)
7. Map coordinates if known

II. SAMPLE COLLECTION

A. Select an area free of surface debris and not directly under trees.
B. Thrust the snow tube vertically into the snow until it touches the ground.
C. Dig the snow away from the tube on one side; read the depth of snow from outside tube.
D. Slide the collecting card underneath the snow tube, just above the ground debris.
E. Life the snow tube and the card.
F. Clean off any snow clinging externally to the tube, then transfer the snow to one of the storage bags and mark the bag with its sample number/team number.
G. Examine the walls of the pit you have dug and look for layers of ice, dirt, etc.

III. ANALYSIS OF SAMPLE

A. Melt the snow sample by placing the storage bag in a pot of warm water. (Do this well away from any open flames. Check for leaks in bag.)
B. Determine the pH: Use the wide range pH paper which gives the pH to within one unit (record). Obtain a more accurate pH reading by using the appropriate narrow range pH paper. Take 3 readings and record them on the Data Sheet.
C. If possible, dry the used pH papers, label them with the sample number, and place them in the used pH paper storage vial.
D. Carefully pour the melt water sample into the small plastic graduated cylinder and record the volume of water of the sample.
E. Dry out plastic snow storage bag and stow it in your pack. Do not burn it. You can use it after the trip.
F. Alternative: carry snow samples to school lab and then analyze.

Name: _____

Address: _____

Group No. and Names: _____

_____

SNOW(pH)ALL DATA SHEET
(SIDE ONE)

Instructions: Complete this Data Sheet by following the directions on the Instruction Sheet enclosed in this packet.

SAMPLE #	DATE	SITE DESCRIPTION
_____	_____	_____
		_____
_____	_____	_____
		_____
_____	_____	_____
		_____
_____	_____	_____
		_____
_____	_____	_____
		_____
_____	_____	_____
		_____
_____	_____	_____
		_____
_____	_____	_____
		_____
_____	_____	_____
		_____
_____	_____	_____
		_____

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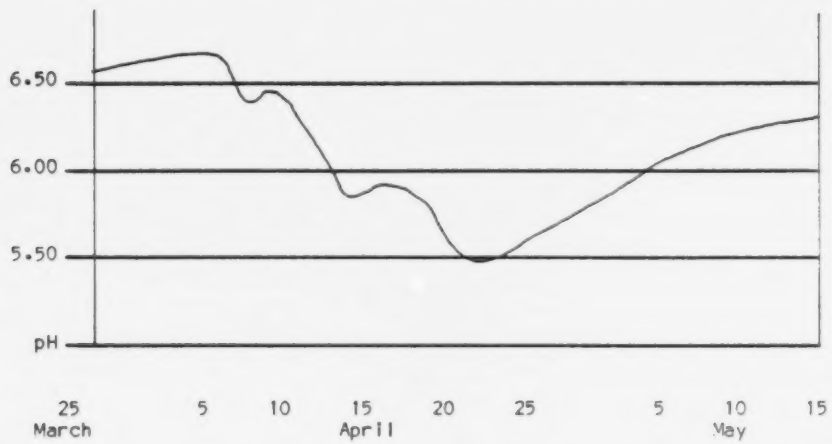
Name: _____

(pH)ALLING SNOW

Use the graph to answer the following questions.

Spring pH Depression of a Stream Entering Harp Lake, Muskoka, Canada



Graph adapted from STILLWATERS: Report of the Sub-committee on Acid Rain of the Standing Committee on Fisheries and Forestry, House of Commons, Canada, 1981, p. 57. Data Collected by Ontario Ministry of Environment, 1980.

1. What is the lowest pH on the graph? When did it occur?
2. What is highest pH on the graph? When did it occur?
3. What period of time does the graph cover?
4. What interpretations (inferences) are justified by the data obtained?
5. What are some further generalizations or hypotheses you can make based on the data?
6. What do you think happened to the pH after May 15?
7. Each full pH unit drop represents a tenfold increase in acidity. Approximately how many more times acidic is the stream on April 10 than it was on March 25?

   Between April 15 and March 25?

   Between May 15 and March 25?
8. Many acid precipitation fishery biologists tell us "For fish, spring can be deadly." What do you think they mean?
9. Does this graph suggest a trend? If your answer is yes, tell why. If your answer is no, make a rough drawing of the graph which would indicate a trend. Title the graph, label the vertical and horizontal axis.
10. What is another experiment this investigation suggests?

SNOW(pH) ALL DATA SHEET
(SIDE TWO)

	GENERAL DATA			METEOROLOGICAL DATA				MAP LOCATION (Opt.)		SAMPLE DATA			pH		
						Snowfall Duration							Narrow Range		
Sample Number	Date	Time	Snow Type	Air Temp.	Wind Dir.	Time Began	Time Ended	Long. Lat.	Snow Sample Depth	Water Content ml / Inches	Melt Water Volume	Wide Range	Trial 1	Trial 2	Trial 3

Physical Sciences

What's natural about preci(pH)itation?

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Overview

The natural pH of precipitation is investigated by simulating natural conditions under laboratory conditions. The work helps students establish the pH of precipitation under conditions not affected by air pollutant emissions.

The work is based on a common assumption: that an equilibrium would be set up with the CO_2 concentration in the atmosphere. Students also explore the limitations of this assumption.

Objectives

Through their experiences in this work, it is hoped that students will be able to:

- describe the influence of carbon dioxide on atmospheric chemistry.
- discuss the natural pH of precipitation under background conditions.

Materials

Each group of students should have:

Test tube 25 x 200 mm
Bromothymol Blue
Glass tube
Graduated cylinder, 25 mL
Tubing, rubber/plastic
Beaker, 30 mL or baby food jars
Rubber stopper, one hole
Clamp, buret, round jaw
Support, rectangular base, steel rod
Indicator paper, blue and red
Marble chips
6M HCl
Distilled water
Data Sheet, An Oxide of Carbon

Optional:
Dry ice

Teacher background

A completely neutral precipitation pH would have a value of 7.0. However, natural precipitation would likely be slightly acidic because the precipitation would tend to come into equilibrium with atmospheric trace constituents, which when absorbed into the precipitation would lower the pH value. Probably the most common assumption has been that an equilibrium would be set up with the CO_2 concentration in the atmosphere and that this would produce a controlling natural pH value of about 5.6. Many acid precipitation investigators have used this CO_2 equilibrium pH value of 5.6 as a criterion to separate natural precipitation pH, any value equal to or higher than pH 5.6; and acidic precipitation pH, any value lower than pH 5.6. This assumption of a CO_2 equilibrated limiting seemed reasonable, since there had not been a considerable amount of precipitation pH data from locations that would not have been influenced by human caused (anthropogenic) pollutant sources.

There is, today, considerable doubt about whether a reference pH value of 5.6 is in fact realistic. Atmospheric chemists have begun to look at all the factors in addition to CO_2 that affect the pH of precipitation. The approach includes both theoretical chemistry and measurements in remote locations of the world. A pH value of near 5.0 may occur as a result of the acidic compunds that occur naturally in the atmosphere. On a global basis, sites vary in terms of the combination of compounds that determine the precipitation chemistry. Therefore, great care must be taken in applying the results to the United States. Dust, for example, by contributing soluble calcium and magnesium ions, can raise "natural" pH values.

The free acidity is the result of the relative contribution of three additional acids: H_2SO_4, HNO_3, and "others" (probably organic acids). Present evidence does not show that natural sources of sulfur oxides, nitrogen oxides and other acid oxides make significant contributions in most continental locations to excessively low pH when compared with anthropogenic sources.

Teacher preparation

1. The distilled water should be pH 7. It is likely that you will have to boil it to eliminate the CO_2, and raise the pH to 7. Cool to room temperature before students use it.

2. Glass items are a major accident source (cuts) in most science departments. You may want to insert the glass tubing into the stoppers rather than have students do this. If students insert tubing be sure that they understand and follow all safety procedures.

3. Before you begin, remind students of laboratory safety procedures. Some states require that the instructor and students wear laboratory safety goggles when working with chemicals. It is appropriate to wear safety goggles when working with any chemicals. This should be a general rule in your laboratory. There should be no exceptions.

4. You can substitute a small piece of dry ice for the marble chips and acid.

Teacher guidelines

1. Distribute copies of the "An Oxide of Carbon" data sheet to your students, review it with them, and have them note any changes in the procedures or the instructions.

2. When students have completed the work, use the data sheet as a basis for a discussion and summary of the work. Have students describe in detail any color changes that occurred. Were the changes gradual or abrupt? What colors were observed? Review the chemistry involved in the laboratory and also discuss their thinking about atmospheric chemistry.

3. Summarize the experience by asking these kinds of questions:

   - What assumptions are made in this experiment?
   - The distilled water was boiled before you used it. Why? What difference would it make if tap water were used instead of the distilled water you used?
   - What would happen to the pH of boiled, distilled water if it were left exposed to the atmosphere? What is an experiment you could do to test your ideas?
   - What changs do you think would occur in the BTB solution if it were left overnight? Why? (Try it.)
   - What might have caused this to happen? How could you find out?
   - How could this experiment be improved, i.e., what experiment might we do to obtain better -- more realistic -- data?
   - If you were trying to determine the natural pH of acid precipitation, what are some environmental factors that should be taken into consideration?
   - How safe are we in assuming that the natural pH of acid rain is affected by atmospheric carbon dioxide? What is your evidence?

NAME(s)_____

CLASS_____

AN OXIDE OF CARBON

1. PREDICTION. The pH of normal rain (natural precipitation) would be expected to be in the acid/base range or neutral. Circle one. What is the reason for your choice? _____

_____

2. INSTRUCTION:

   a. Obtain the following equipment: test tube, clamp, support, rubber stopper, glass tubing, rubber/plastic tubing, beaker, graduated cylinder.

   b. Set up the equipment as indicated by your teacher.

   c. Place about 25 mL of distilled water in the beaker. Test with litmus paper. Record the results of this test.

   d. Add about 12 drops of bromothymol blue to the water. Test with litmus paper. Record the results of this test.

   e. Place a small amount of marble chips into the test tube, add 10 mL of 6M HCl, reconnect the apparatus and let the gas released bubble through the water.

3. Describe <u>in detail</u> any evidence of change in the system.

4. Test the solution with litmus paper. Record the results of this test.

5. What might have caused any changes you observed?

6. On the back of this sheet write a report of your experiment. It should have four sections: purpose (statement of question or hypothesis), procedures, observations, and the interpretation of the results.

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Cartoon(pH)un?!

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Overview

Students examine cartoons and gain additional perspectives on acid precipitation. The cartoons are used to stimulate discussion about values, science, and society.

Objectives

After completing this activity, students should be better able to:

- list the values expressed or implied.
- compare the cartoonist's values and judgments with their own values and point of view.
- describe the issues, people, or events shown.
- interpret the message or viewpoint.
- identify the frame of reference and biases of the cartoonist.
- understand that cartoons often exaggerate for emphasis.
- recognize that cartoons are much more likely to identify problems than to offer solutions.
- appreciate the editorial functions of cartoons.

Materials

Collection, Acid Rain Cartoons
Cartoon (pH)un Worksheet Cards
Overhead Projector

Teacher Background

1. Cartoon Collection. The collection of acid precipitation cartoons which is included in this activity is a small one. Encourage your students to add to it. Cartoons on acid precipitation will be found not only on the editorial pages of your newspaper, but also in a wide variety of magazines. When cartoons are clipped or photocopies made, be sure students include the source of the publication and the date, e.g., Minneapolis Tribune, November 1, 1980, or Sports Afield, August, 1981. (These are examples only; neither one, to our knowledge, contains an acid precipitation cartoon.)

   When you/your students find a new cartoon, please send a copy of it to: The Acid Rain Foundation, Inc., 1630 Blackhawk Hills Road, St. Paul, MN 55122. We want to add cartoons to our collection and also to this activity so that others can benefit from your research.

2. Copyright. In an article in the The Science Teacher, September, 1980, Larry Schafer discussed the issue of copyright and classroom use of cartoons. "Nearly all copyrighted materials carry a statement indicating that written permission of the publisher or author is necessary if all or any part of the materials is to be reproduced. The 'fair use' provisions of the new copyright law, however, make compliance with these statements unnecessary providing: (a) the material is for nonprofit educational purposes; (b) the potential market for, or value of, the copyrighted work is not substantially reduced; (c) the amount of material copied is reasonably minimal; (d) the decision to use the copyrighted material is 'spontaneous'; and (e) the copied material is not used in future courses within the same educational setting."

   "These provisions will likely be met if you occasionally make single copies of cartoons for use in your science class. To safely use multiple copies, make no more than one copy per student, copy no more than one cartoon from any book or periodical, and limit the distribution of copies to one course. For use of cartoons beyond the provisions described, write to the copyright holder or publisher and ask permission for the specific use of the cartoon. In most cases, permission will be quickly granted."

3. Editorial Cartoons. The collection of cartoons with this activity includes both editorial and regular cartoons. They are not clearly identified. However, the cartoons from newspapers are more than likely from the editorial/opinion pages. If you are not familiar with the use of editorial cartoons, some information about them is included. This information can provide you with ideas for your own questions about cartoons. In addition to questions about the cartoon, ask students to identify the artist and the source.

   Cartoons printed on the editorial page are called Editorial Cartoons. More than entertainment, they express a strong opinion or a special point of view about a person or an issue. Editorial cartoons have a purpose: change. They may try to change the reader's mind, influence an elected official, or to tell us something that, in the opinion of the cartoonist, ought to be changed. Some of the characteristics of the editorial cartoons include:

   EXAGGERATION. Objects or people are larger than they should be. Reality, too, is exaggerated.

   PERSONIFICATION. Institutions such as big business, unions, government, etc., are frequent subjects of this technique.

   COMPARISON. Editorial cartoons often demand background knowledge to understand them. By comparing what is going on with something the reader is likely to know or be familiar with, cartoonists provide a context for understanding.

   CARICATURE. Usually of government people.

   DOUBLE MESSAGE. When this device is used, one is obvious and the other is hidden. This is a little like a puzzle. It slows the reader down with the hope that with more careful scrutiny and examination the reader will be convinced.

   SINGLE TOPIC. The emphasis is simplicity. However, both the form and content may be quite complex.

   PROBLEM STANCE. More identify problems than offer solutions, although solutions may be implied.

BIASED. Express a particular viewpoint and values. On the other hand, a cartoonist might argue that s/he has abstracted the essence of an issue.

STEREOTYPES. Groups and individuals can be misrepresented.

SYMBOLS. As compared to the lifelike representations of photographs, cartoons contain fewer details and use symbolic representations of reality. As familiarity with the conventions of the cartoonists' nonverbal language is gained, editorial cartoons become easier to "read."

CURRENT. The topics are of current events and often tend to be on broad issues, for example, statewide, regional, national, or international. They can, of course, be quite focused on a local issue.

HUMOR, SATIRE, RIDICULE. A strong combination! The reader may not always be aware of the influence these have.

In recent years, electric utilities appear to have contributed to more than half of the total sulfur oxide emissions. Highest SO_2 emissions occur in the Midwest and within a 31-state region, the five highest levels of estimated SO_2 emissions for 1980 occurred in Ohio, Indiana, Pennsylvania, Illinois and Missouri. (The areas of highest emissions densities shifted from the North Atlantic Central region in the 1950s to the Midwest in the 1970s.)

Sulfur (S) occurs in the atmosphere (troposphere) in diverse forms involving oxidation states from -2 (H_2S) to +6 (H_2SO_4). Some aspects of the chemical mechanisms of SO_2 oxidation are not well understood; the final product is a sulfuric acid aerosol.

In general, deposition from a pollutant source is greatest near the source and decreases more or less exponentially away from the source. In the summer, on the average, well over half of the eastern U.S. sulfur emissions may be deposited within two days and 500 km. from the source. The transport range is likely to be considerably greater in winter. The prevailing flow of the pollutant is referred to as downstream. In the ecologically sensitive regions of eastern North America, downstream generally means toward the east/northeast.

Teacher Preparation

1. Laboratory safety. It is strongly recommended that you do not do this work, either as a demonstration or as a student activity, unless you and your students wear eye protection. It may be required in your state. There is a general rule. When you work with chemicals: Wear Safety Goggles! The work involves a flame and an acid.

   When generating a toxic gas such as sulfur dioxide in the laboratory, use a fume hood. The hood should not be used for chemical storage. The room should be well ventilated.

2. Litmus paper. A large supply of litmus paper can disappear in a hurry. Pre-cut litmus to appropriate lengths (1 cm.) or make your laboratory instructions very clear.

3. The solution which results from burning the soft coal or sulfur is a weak acid and may not always be strong enough for dramatic changes, e.g., bubbles to be observed when it is added to pieces of marble. Use as large a gas generating bottle as you can and also make a backup. You can also try oxidizing the solution with a few drops of H_2O_2.

Teacher Guidelines

1. When using cartoons, be sure the cartoon is visible to your class. Either make copies of the cartoon(s) for the class or use an overhead projector. Ask students questions about comprehension, values, attitudes, bias, and the agreement between facts and the cartoonists' slice of reality.

2. Ideas for using acid rain cartoons are found on the "Cartoon (pH)un Worksheet." Distribute copies of appropriate cards and use them as a basis for study and discussion. The cards are not mutually exclusive.

3. Conclude the lesson with a discussion. Use some of these kinds of questions:

   - What are some things we can learn from cartoons?
   - An opinion is support for argument only when the person expressing the opinion is in a unique position to know, observe, and interpret given facts about acid rain. If s/he is, why? If s/he is not, who is? Why?
   - Acid rain (deposition) is a fact. Is it also a value?
     a. What are some values that characterize current society? (List student responses on the board.)
     b. Now think about these values and acid rain. For those values that serve a useful purpose, put a plus (+) beside them. For those values that do not serve a useful purpose, put a minus (-) beside them. For those you think neutral, put an N beside them. What are some reasons for your choices?
     c. How do you think adults would rate these values? If there are differences, how do you account for them?
     d. What values will still be good ones when you are 30? (Put that year on the board so that students can focus on it.)
     e. For those values that should be changed in the future, how would you change them? What should replace them?
   - Is acid rain a social problem that has arisen because of scientific discoveries?
   - Is acid rain a social problem that is likely to be solved because of scientific discoveries?
   - After examining the cartoons and thinking about the information in each, is this a "cartoon view" of acid precipitation? Why or why not?
   - Ask students to copy the following sentence stems on a separate sheet of paper. Then ask them to finish each sentence. Students are not to write their names on their papers.

When it comes to acid precipitation...

Most people think acid precipitation is...

Ten years from now, acid precipitation will be...

I think acid precipitation is...

The most frustrating thing about acid precipitation is...

Acid precipitation cartoons...

When the class is finished completing the sentences, collect the papers and place them face down. Shuffle and mix the papers up, then distribute the answers to the class. Ask a few students to read answers to statements from the papers.

- Put this test on the board:

  The correct tool for learning about acid precipitation is

  a. the cartoon
  b. a newspapers article
  c. a magazine article
  d. a scientific report
  e. a television documentary

  What reasons do you have for saying that?

  Suppose this test item also contained these choices:

  f. All of the above
  g. None of the above

  Would this change your original answer? Why or why not?

Name: _____

Class: _____

Cartoon (pH)un Worksheet Cards

What is the main point the cartoonist is making? Do you agree with it? Why or why not?

According to the cartoon, what is the major "problem" or issue associated with acid rain?

Does the cartoon provide you with a true picture of the way things are today? What are some reasons for your choice?

What are the biases and assumptions of the cartoonist? What does s/he like and dislike or approve or disapprove?

Has acid rain hurt any natural area, agricultural system, or the human-made environment (cars, buildings, statues)? In what ways? How sure are you?

What is the topic of the cartoon?

What is exaggerated?

Does the cartoon make a comparison? If so, what is it? What is the purpose of the comparison?

What is the message? Do you agree or disagree?

Is there a double message - one that is obvious and one that is hidden? What are they?

A fact is something that is known to be true, to exist or to happen, in the present, or in the past. What facts do you find in the cartoon?

An opinion is an interpretation of facts or a judgment of value concerning them. What opinions do you find in the cartoon?

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Circle the number on the scale which most closely matches your attitude about the cartoon.

Funny	5	4	3	2	1	Not Funny
Interesting	5	4	3	2	1	Uninteresting
Fresh	5	4	3	2	1	Stale
New, Different	5	4	3	2	1	Common, Ordinary
Lively	5	4	3	2	1	Lifeless
Distorted	5	4	3	2	1	Undistorted
Meaningful	5	4	3	2	1	Meaningless
Good	5	4	3	2	1	Bad

Write a short paragraph describing exactly what you see in the cartoon. Read your paragraph to the class. Are the same cartoons translated differently? What are some reasons?

Write a sentence or two on how the issue in the cartoon relates to you.

If you were writing a report on acid precipitation or trying to make a point about acid rain, would you use this cartoon? In a sentence or two describe your reasons.

After you have examined a collection of cartoons, what issue/issues do they deal with? Check the boxes which apply.

_____ business	_____ ecological
_____ health	_____ political
_____ scientific	_____ social
_____ economic	_____ pollution

Tell why you made the choices you did.

Can you group all of the cartoons under this set of categories or do you need new ones?

Write down the first word each cartoon makes you think of. When you are finished, find out what your classmates thought. Many of the words may be about what one would expect, but you may find a surprise now and then. This is the time to ask, "How did you come to think of that?"

After you have examined a few cartoons, indicate whether you agree or disagree with the following statement.

> Cartoons are much more likely to identify problems than to offer solutions, although sometimes solutions may be implied.

Agree Disagree

Write a sentence defending your choice.

In cartoons where solutions are implied, what are they? Would a scientist agree with them? A politician? An environmentalist? An organism?

Are the proposed solutions good for the ecosystem? The social system? How do you know?

What other forms of visual resources does the cartoon remind you of: a photograph? a drawing? a painting? a model? a chart? an advertisement?

Does the cartoon's message depend on your having learned certain nonverbal cues? Why or why not? What are they?

Do you suppose a person from a totally different culture would get the same message?

Which, if any, of the following concepts from science can you find used or referred to in the cartoon: population, species, predator/prey, food chain, environment, habitat, community, producers, consumers, decomposers, interaction, responses of organisms, pollution, optimum water cycle?

What environmental factors can you find? Abiotic factors? Biotic factors?

According to the cartoonist, how does acid rain change the environment?

Is s/he right? What is the evidence?

What is the problem?

Do you consider this a problem? How serious is it?

What is the artist's hypothesis, that is, a tentative conclusion that could be tested by means of research?

What solution to the problem would you suggest?

What about the cartoon struck you most or stuck out?

What ideas or beliefs or feelings do you bring to the cartoon that could influence the way you "read" it?

What do you like about the cartoon? Dislike?

Summarize the cartoon. In one sentence summarize your understanding of it. Then in one word.

Describe the issue, people, situation or event.

What single item is emphasized?

How does the cartoonist emphasize the message? What symbols does s/he use?

What is the viewpoint of the cartoonist?

What is your view of the artist's message?

What follows from what the cartoonist says?

What beliefs is it based on?

What arguments could the cartoonist use in support of the claim s/he makes?

What alternatives are there to such a formulation?

Social Sciences

What are the (pH)ossibilities?

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Overview

The implications of futures wheel is one of the most popular and useful conceptual tools in the futurist's tool kit. It can be used to imaginatively explore the domain of the possible. In this activity, students use this multiple right-answer tool to explore the implications of acid deposition.

Objectives

Through their experiences in this work, it is hoped that students will be able to:

- o use a tool designed for understanding and dealing with problems of a systemic nature.
- o discuss their responsibility for the future.
- o sense the importance of their involvement in complex and long-term environmental issues.

Materials

Overhead projector
Newsprint/butcher paper
Markers/crayons

Teacher preparation

1. The futures or implications wheel is a tool which is used to explore the possible. It is not a decision making tool. It can be used to dramatically increase awareness of some of the implications of: trends, innovations, policies, or goals. It will take about one period to teach students to use the futures wheel.

2. TO USE THE FUTURES WHEEL:

A. START A DIAGRAM
(An incomplete example of an implications wheel is included.)

Write the trend/innovation/policy/goal in the center of a sheet of paper, chalkboard or on an overhead transparency. Circle it.

B. ASK ONE OF THESE QUESTIONS:

1. What might occur as soon as (trend, innovation, policy, or goal) is introduced to society?

OR

2. What might happen if (trend, innovation, policy, or goal) continues to (increase, decrease, occur) in the future?

C. RESPONSES

As students respond, place the responses around the central "hub" or node, circle each one and connect it with a single line to the central node. These responses are called first order implications. They are indicated by a single line.

D. NEW IMPLICATIONS

For each of these nodes or first order implications ask: What things might occur as soon as this possibility happens? Connect the new implications with two lines. Continue this processs for about four or five orders of implications.

Third order implications are connected by three lines; fourth order implications by four lines and so forth. Futures wheels can get out of control — sixth order implications represent a natural upper limit.

E. WHEEL RUNNING: SOME SUGGESTIONS

1. Stop discussion on a possibility as soon as everyone agrees and move immediately to another possibility. Discussion can have a stultifying effect.

2. Participants should describe a possibility in as concrete terms as possible.

3. It is important to work in concentric circles rather than in chains.

4. Try to make at least one positive and one negative comment at each node.

5. All possibilities are okay. The criterion is that there is agreement that a suggestion is possible.

6. Do not be critical of suggestions. If you think the suggestion is not possible, ask for an explanation and seek agreement on it. You (or someone else) may also raise a question about the order of the possibility. When you do, just make a simple statement: "I believe that another (trend, innovation, policy, or goal) is more likely to occur before the one suggested"; then state and discuss it.

7. Repetition is okay.

8. Contradictory responses are okay. Both may be possible.

9. The recorder is a RECORDER. S/he may, with permission, edit especially long comments.

F. GROUP SIZE: USE THE FUTURES WHEEL

1. First, with your entire class so that students gain familiarity with it.

2. Then, with small groups (4-6). Small groups will generate more possibilities than the entire class. These can be compared and discussed.

G. SOURCES OF TOPICS

Newspaper articles, television documentaries, and magazine articles about acid precipitation.

Teacher guidelines

1. Lead a class exploration of any area of interest--it does not have to be acid rain--to introduce your students to the futures wheel and to give them some experience in using it. Be sure that all students can see. Use an overhead or chalk board or a big sheet of newsprint.

   For an innovation, ask: What things MIGHT occur as soon as this innovation is introduced? (Circle the innovation and place it near the center of the overhead/paper/board.)

   For a trend, ask: What things MIGHT occur if trend X continues to (increase, decrease, or stay about the same)?

2. Then, divide your class into small groups of four to six and give them an acid deposition trend/goal/policy/innovation (a new technology).

3. There are several ways to score the wheel. Have students use one (or more) of the following:

   a. Decide whether each effect is Good (G) or Bad (B).

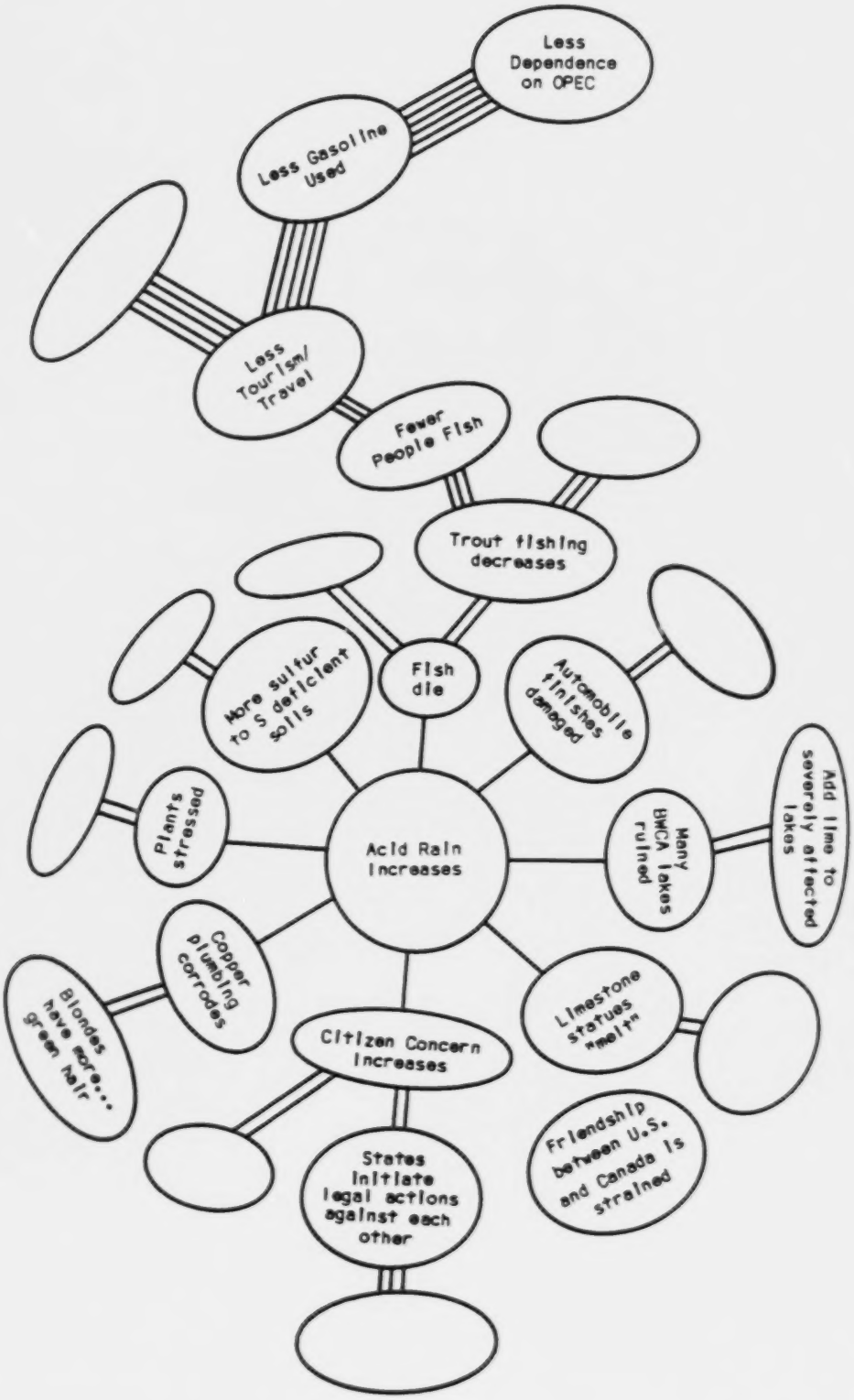
   b. Assign probabilities to each effect on a scale of 1-5 with 1 being almost sure that it will happen and 5 being almost sure that it will not happen.

   c. Is the trend, innovation, goal, or policy something that you would like to see happen? (Y = yes; N = no) Why or why not? What can you do about it?

4. Discuss each group's futures wheel. Use these questions to stimulate discussion:

   - How are the futures wheels similar and different from one another?
   - Were some implications considered in only one group and not any of the others? What are the reasons?

5. Conclude the activity with a discussion. Use these kinds of questions:
   - The futures wheel is not a decision making tool. How could it be used to influence or to help us make better decisions?
   - What are some highly desirable possibilities? What are some things that could be done to make them happen?
   - What are some of the highly undesirable possibilities? What are some things that could be done to decrease their probability?
   - How do you think people can become better informed about issues related to acid deposition?


Less Dependence on OPEC
Less Gasoline Used
Less Tourism/ Travel
Fewer people fish
Trout fishing decreases
More sulfur to S deficient soils
Fish die
Automobile finishes damaged
Plants stressed
Acid Rain Increases
Many BWCA lakes ruined
Add lime to severely affected lakes
Copper plumbing corrodes
Blondes have more... green hair
Citizen Concern Increases
Limestone statues "melt"
Friendship between U.S. and Canada is strained
States initiate legal actions against each other

EXTENSION. This activity can be used to monitor implications. This will require students to keep abreast of current events and to identify the implications that really do occur as well as identify unthought of implications. These real data can then be used as the basis for the exploration of implications.

THANKS!

The Futures Wheel was developed by Jerry Glenn, a professor at the University of Massachusetts. Joel Barker, Infinity Limited, St. Paul, Minnesota, has clarified, enhanced and refined the futures wheel. It has proven to be a powerful tool and has been used successfully with kindergarten students as well as adults. It is a pleasure to acknowledge Professor Glenn and Joel Barker. Ideas and materials developed by Joel Barker have been used with his permission.

Social Sciences

Collecting points of (pH)iew: An acid precipitation sur(pH)ey

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Overview

Surveys are used by sociologists, political scientists, the news media, and politicians to assess public attitudes about a variety of issues. They can be used to assess needs for new programs, policies or services, determine public awareness, evaluate the quality of existing programs, policies or services, involve citizens in the process of program and policy development, and educate the public about programs, policies, or issues.

In this activity, students will gain experience in developing and selecting questions, sampling, and in summarizing and analyzing data.

Objectives

Through their experiences in this work, it is hoped that students will be able to:

- use a questionnaire to gather information about acid rain.
- measure the degree of interest regarding the issue of acid rain.
- identify and choose the people to be questioned in order to gather needed information.
- compile, tabulate and analyze survey results.
- interpret and make sense of the information gathered in a questionnaire.

Materials

MATERIALS: SAMPLE QUESTIONS

Teacher preparation

1. This activity requires some background on acid precipitation. After showing a slide-tape, film, or completing a lesson on acid rain ask your class some of these kinds of questions:

   - What do you think people know about acid rain?
   - What are some attitudes people have about acid rain?
   - How aware do you think people are about existing acid rain programs or policies?
   - Where do you think people obtain information about acid rain?
   - What are some ways we could find answers to these kinds of questions? What are the advantages and disadvantages of each?
   - Is public perception about acid rain worth caring about? Will anybody care about the results?
   - What is the purpose of a questionnaire about acid rain? What are we interested in learning about?
   - What kinds(s) of information do we need to fulfill the purpose of the questionnaire?

2. Divide the class into small groups and ask them to develop a few questions about acid precipitation that fulfill the purpose of the questionnaire. The sheet, Sample Questions, contains a <u>few</u> examples of questions and response formats. If you have large sheets of newsprint, have students write their questions on them. When they are finished, one person in the group should post these lists on the wall. A second person should be prepared to give a brief report to the class on their group's questions. After all groups have reported, make some decisions about the questions, e.g.,

   - draw lines through questions which are repetitive or which are not necessary or which do not fulfill the purpose of the questionnaire.
   - circle items that absolutely must be asked.
   - draw boxes around items that should be asked, but which require more clarity to avoid confusion.

3. Transfer the questions from newsprint to standard sheets of paper and have copies ready for the class the next time you meet. You may want to clarify the ambiguous or confusing questions. Ask these questions to guide a discussion of the survey:

   - Are all of the questions clear?
   - Do we have enough questions or too many questions? What ones are we going to eliminate?
   - How are people supposed to respond to the questions? Completion? Agree-Disagree? Should we also ask the intesity of agreement-disagreement? True or False? Rank-order?
   - How will people know what the purpose is? Should the questionnaire contain a brief statement describing its purpose? What should it say?
   - What additional information is needed on the form? Date? Age? Sex? Instructions?
   - How are we going to assure confidentiality?

4. Now, ask some questions about the sample, e.g.,:

   - How many surveys will we do?
   - Who should we survey? Our class? School? Community? Should the sample include different age groups? Which ones? Should the group be balanced, i.e., same number of adults and students?
   - When is the survey to be completed?

5. Now, ask some questions about the distribution and collection of the survey, e.g.,

   - How are we going to distribute and use the questionnaire?
   - Who is going to complete the survey? The respondent or the person doing the survey?
   - If we are going to use the survey as an interview, what do you need to say to introduce yourselves?
   - If we are going to leave forms in another classroom or at a local store, what are you going to say to the person-in-charge, to introduce yourself?
   - How will we get forms back?

6. Make a final copy of the questionnaire and give copies to students for distribution. They should find other students or adults who will complete the questionnaire for them. They should bring the completed questionnaires back to class within three days.

7. If possible, before class the students should tabulate the results of their surveys. Divide the class into small groups and have them compare and summarize the results of their surveys. Then, post the tabulations of results from the survey so all students can see them.

   For some of the questions you may want students to calculate percentages. Percentages are calculated as follows: Divide the number in each category by the total number, then multiply by 100 to obtain the percentage. For example, the number of adults who feel that other countries have done more than we have about acid rain is 20. The total number of adults is 50. To determine the percentage, divide 20 by 50 and multiply by 100, that is:

   $$\frac{20}{50} \times 100 = 40 \text{ or } 40\%$$

8. Ask these kinds of questions to guide a discussion of the survey results:

   - Did students run into any problems? What kinds? How did they solve them?
   - Did people you surveyed ask you any questions about acid rain? What were they?
   - Were the survey questions clear? What is your evidence?
   - Do the people surveyed have a clear understanding of the issues associated with acid rain? What is your evidence?
   - How do people tend to view acid rain? What is your evidence?
   - How representative is our data? How could it be improved?
   - What are some of the similarities and differences you observe?
   - Do people seem to be interested in acid rain? What is your evidence?
   - What do you make of the evidence? What are all the possible interpretations?
   - How could we be more certain of conclusions we reached from the data?
   - Ask students to write a newspaper headline they would use in an article about their findings.
   - Have students write a topic sentence for a paragraph in which they use the survey data. Collect the sentences, mix them up and read them aloud or distribute them and ask students to read them.
   - Ask students to complete these statements:

     If I were to conduct an acid precipitation survey ten years from now, I would find...

     Acid rain is...

     The most frustrating thing in conducting a survey is...

     When it comes to acid precipitation...

SAMPLE QUESTIONS

AGREE-DISAGREE

If you STRONGLY AGREE (SA) with the statement, circle number 1.
If you AGREE (A) with the statement, circle number 2.
If you have NO OPINION (NO) about the statement, circle number 3.
If you DISAGREE (D) with the statement, circle number 4.
If you STRONGLY DISAGREE (SD) with the statement, circle number 5.

Be sure to circle only one number for each statement.

	SA	A	NO	D	SD
1. More must be learned about acid rain before it can be regulated. (circle one)	1	2	3	4	5
2. Acid rain is a present and severe danger.	1	2	3	4	5
3. Failure to act promptly on acid rain will soon result in untold and irreparable damage to the forests, agriculture, fish, wildlife and buildings/statuary of the state.	1	2	3	4	5
4. States should be allowed to bring legal proceedings against polluters from outside their state.	1	2	3	4	5
5. Those receiving acid precipitation pollution should have as much to say about the issue as the producers of this pollution.	1	2	3	4	5
6. The biggest concern about acid rain is regional-scale air pollution rather than local air contaminants.	1	2	3	4	5

CIRCLE ONE

7. I agree/disagree that the causes of acid precipitation are well known.

8. I agree/disagree that acid precipitation emitters should be required to meet national standards.

9. We should have less, about the same, more regulation of emissions from coal-fired power plants (or automobiles and trucks).

RANK-ORDER

10. Rank order the potential acid rain impacts from most important (1) to least important (7).

_____ Health _____ Economic _____ Buildings

_____ Forest _____ Soil _____ Statuary

_____ Wildlife

COMPLETION

11. How have you learned about problems and issues related to acid rain? _____

12. Do you talk about acid rain with your friends?

_____ a. Yes

_____ b. No

13. How often have you tried to influence a person about an issue associated with acid rain?

_____ a. Five or six times

_____ b. Three or four times

_____ c. Once or twice

_____ d. Never

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14. How often do you watch television programs about public affairs and the news?

_____ a. Almost daily

_____ b. Two or three times a week

_____ c. Three or four times a week

_____ d. A few times a year

_____ e. Never

15. How much do you know about acid rain? _____

OPINIONS

16. a. When it comes to acid rain, do you think we can trust the government in Washington to do what is right? _____

b. With respect to acid rain, would you say that the government in Washington is generally run for the benefit of a few big interests or that it is run for the benefit of most of the people? _____

c. Do you think we can trust the state government to do what is right about acid rain? _____

d. Do you think you can trust industry to do what is right about acid rain? _____

e. Do you think you can trust the car-buying public to do what is right about the rain?